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(U.S.) Environmental Protection Agency, Washington, DC

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Symposium on Recycling Water Supply Systems and Reuse of Treated Water at Industrial Plants

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Working Group
on the Prevention of
Water Pollution
from Municipal and
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Moscow—U.S.S.R.
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The fifth cooperative USA/USSR Symposium on the Recycling Water Supply Systems and Reuse of Treated Water at Industrial Plants, was held in the Soviet Union at the Moscow Headquarters of Gosstroy on September 12 and 13, 1977. This Symposium was conducted in accord with the fifth session of the Joint USA/USSR Commission held in Moscow, USSR, from November 15 through 19, 1976.

The fourteen (14) papers that were presented at the Symposium (seven USA and seven USSR) are reprinted in English in this volume in accordance with the protocol signed by the delegation leaders on September 23, 1977.

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Index

Preface 1

Welcome — *New Developments for the Reuse and Recycling of Wastewater in the U.S.A.* — **Harold P. Cahill, Jr.** 2

Paper Presented at the USA/USSR Symposium

Alferova, L.A., Nechaev, A.P., Markov, P.P. (All-Union Scientific Research Institute, "Vodgeo"), *Fundamentals of Creating Closed-Loop Water Supply Systems at Industrial Enterprises* 4

Lacy, William J., (US EPA), *The Closed-Loop Cycle for Industrial Wastewater, The Future Pollution Solution* 6

Ioakimis, E.G., Saifutdinov, K.Z. Yefimova, A.K., (Bashkirian Scientific Research Institute of Petroleum, USSR), *Usage of Purified Waste Water in Refinery Circulating Water Systems* 17

Peltier, Eugene J., Cairns, Donald F., Buzzell, James C., (Sverdrup and Parcel, USA), *Recycling — The Key to one Steel Mill's Pollution Control Program* 20

Sukach, S.P., Klovatskiy, Yu. D., Shenderovich, I.B., Kharkov, (Division of VNII VODGEO, USSR), *Utilization of Sea Water in a System of Recycling Water Supply of Industrial Enterprises* 24

Sebastian, Frank P., Lachtman, Dennis S., (Envirotech, USA), *Municipal and Industrial Wastewater Treatment and Reuse* 26

Casanov, M.V., Amirova, S.M., (All-Union Research Institute VODGEO, USSR), *To the Question of Municipal Treated Sewage Use in Industrial Water Supply of the Apsheron Peninsula* 32

Tillman, Donald C., (City of Los Angeles, USA), *Water Reclamation as a New Dimension in Growth for Los Angeles* 35

Lukinih, N.A., (USSR), *The Peculiarties of Municipal Sewage Effluent Utilization in Industrial Plants* 38

Rimkus, Raymond R., Knight, Earl W., Lynam, Bart T., (Metropolitan Sanitary District of Greater Chicago, USA), *Reuse of Process Water from a Large Steel Plant* 40

Sukach, S.P., Kirichenko, A.G., Shenderovich, I.B., Antonchuk, J.I., (Kharkov Division of VNII VODGEO, USSR), *Conditions of Municipal Effluents Use for Marking Up Of Recycling Water Supply Systems* 44

Gellman, Isaiah, (National Council of the Paper Industry for Air and Stream Improvement, Inc., USA), *The Role of Wastewater Reuse and Process Loss Control in Paper Industry Wastewater Management* 47

Nikitin, J.W., (Leningrad, USSR), *Closed Up Water Supply Systems and Reuse of Treated Effluents in the Pulp and Paper Industry of the USSR* 54

Protocol 59

Appendix 1
Participants 61

Appendix 2
Papers Presented 61

Appendix 3
Future Program 62

Appendix 4
Symposium Program 64

USA-USSR WORKING GROUP on the Prevention of Water Pollution from Municipal and Industrial Sources

Symposium on Recycling Water Supply Systems and Reuse of Treated Water at Industrial Plants

United States
Environmental
Protection
Agency
Moscow-USSR
September 12th
and 13th, 1977

Preface

The fifth cooperative USA/USSR symposium on the Recycling Water Supply Systems and Reuse of Treated Water at Industrial Plants was held in the Soviet Union at the Moscow headquarters of Gosstroy on September 12th and 13th, 1977. This symposium was conducted in accord with the fifth session of the Joint USA/USSR Commission held in Moscow, USSR from November 15 through 19, 1976.

This symposium was sponsored under the auspices of the Working Group on the Prevention of Water Pollution from Municipal and Industrial Sources. The co-chairmen of the Working Group are H.P. Cahill, Jr. of the United States Environmental Protection Agency and S.V. Yakovlev of the Department of Vodgeo in the Soviet

The United States delegation was led by Harold P. Cahill,
Union.
Jr., Director Municipal Construction Division, U.S. Environmental Protection Agency.

The fourteen papers that were presented at the symposium (seven US and seven USSR) are reprinted in English in this volume in accord with the protocol signed by the delegation leaders on September 23, 1977. □

New Developments for the Reuse and Recycling of Wastewater in the U.S.A.

Address by Mr. Harold P. Cahill, Jr.
Municipal Construction Division
U.S. Environmental Protection Agency
Washington, D.C.

It is a great pleasure to join you here. I look forward to participating in these meetings with our distinguished Soviet colleagues, and I regard my experience working with this group as one of the most highly rewarding of my professional career.

The symposium topic is very timely and of considerable interest in the United States at present. I expect the contributions to the treatment field to be especially significant from our joint efforts. I can promise that the practices in the Soviet Union that promote the recycling and reuse of wastewater, as they are presented here, will be very closely attended by myself and my colleagues.

The municipal wastewater treatment control program has had, as the one of its goals, the development of systems and practices that provide for the reclamation and recycling of water. That purpose was written into our basic law, the Federal Water Pollution Control Act as amended in 1972.

A good example of the kind of systems that policy would encourage is the land treatment project in Muskegon County, Michigan, which was officially dedicated in July, 1976. Some of you have visited that project, and I commend your interest. Our purpose today is to examine how the potential benefits from such projects can be expanded to meet the varying needs and conditions of our peoples.

A number of developments in the United States have recently been converging to focus our efforts on greater encouragement of what we term "alternative treatment systems" within our program. That is a very broad term which encompasses a number of systems—employing new and old technology—which meet the requirements within our program resource and energy conservation, and cost saving.

As you may know, our program is reaching the end of its initial $18 billion in funds, and obligation are expected to almost consume the remainder of those funds. Further funding for the program is being considered by our Congress, and bills have been prepared in both the Senate and the House of Representatives to provide the needed monies. We believe that this amount, along with 25 percent more in matching state and local funds, will fulfill our estimated priority needs for basic municipal wastewater treatment facilities.

Extended funding was recommended earlier this year by President Carter, who advocated long term support for the program, totaling $45 billion to be available for 10 years at $4.5 billion per year. The President's message reaffirmed that continued commitment of heavy public funding to the program must be based on meeting the environmental objectives of cleaning up and maintaining the quality of our waters. The President was concerned that the program monies be spent on building those projects which take care of the highest priority needs, represent the most cost effective solution to the treatment problem, and will not lead to secondary impact resulting in even greater environmental problems in the water and the land.

This strong Presidential support is a development of major importance to our program, along with the President's condition that our funding priorities be environmentally formulated under the law and observed.

The two bills I mentioned, in the Senate and House of Representatives, contain funding provisions of $17 billion for 3 years in the House version and about $23 billion for 5 years in the Senate version. It is impossible to predict what the outcome of the joint conference deliberations of the amendments would produce, but I believe it is safe to say that further funding for the program will result since we have only traveled one-third of the distance toward meeting our goal of providing secondary treatment to our municipalities.

There are other program-impacting provisions in the two bills that would encourage and reaffirm the goals of resource conservation and recycling in the Senate bill, for instance:

—State project priority lists, which list projects in order of importance for funding, would include consideration of recycling, reclamation, and alternatives to conventional systems in their development . . . all goals of the basic Act.

—Also, the requirement for pretreatment to remove industrial pollutants impairing the usefulness of municipal sludge or interfering with treatment processes, would be strengthened: and, pretreatment requirements would be integrated into federal-state permits.

There are other such provisions included in the Senate bill, as well. But I mention these because of their importance. It is likely that some of these will pass through the joint conference committee process and be approved by the Congress and the President for incorporation into our law.

As for the prospects for projects for reuse and recycling, there are various other factors beating upon the program.

First, we are reaching a point where we are beginning to fulfill many of the needs of our larger communities. The smaller communities will be receiving more attention and funds, but many cannot sustain expensive capital and operating and maintenance costs, nor provide the trained personnel necessary for sophisticated advanced systems. However, many could undoubtedly provide suitable vacant land nearby for siting land treatment systems. We are currently funding land application in about 13.5% of our projects at the design and construction stage, but I believe we are just scratching the surface of the potential demand for alternative solutions.

Second, the increased demands for water are becoming increasingly apparent to our policy makers.

Third, the high incidence of cancer and its increasing link to water pollution and the toxic pollutants is generating support from the public for our mandated programs to pretreat industrial wastes, enforce the goals of the Act, and issue standards for toxic pollutants.

Fourth, the burden of costs to accomplish such program objectives as universal secondary treatment in our communities is beginning to be appreciated. While our level of obligations to projects is about $6.5 billion this fiscal year, our federal expenditures are approaching $4 billion, (6 billion plus total) and we expect them to exceed $5 billion (i.e. percentage plus) next year. This is a considerable sum of money, I am sure you will agree. In fact, I recently estimated what $1 billion would amount to if it were laid out, end to end, and I concluded it would extend to the moon and back.

As a nation, we are using about 400 billion gallons of water each day, and that figure is expected to double by the end of the century. Drinking water demand is projected to increase from 30 billion gallons to 50 billion gallons all of which must be clean, safe and potable.

The impact of toxic pollutants on public awareness and general support of environmental initiatives, coupled with the passage of the legal deadline for installation of secondary treatment in municipalities and best practicable treatment in industries by July 1, 1977 has enabled us (EPA) to sue several major cities—Los Angeles, Detroit, and Memphis, for example—and various other smaller communities as well as offending industries. Actually 95% of our industries are in compliance whereas two years ago it was thought impossible. We are just beginning this effort, but the important effect to consider from the program view is the impetus to construction these federal enforcement actions will provide. Our pretreatment regulations will require industries discharging to city systems to treat any wastes which might harm municipal plants or pass through untreated. We expect the regulations to reach the stage of promulgation for implementation within the next few months, and this will further encourage construction and ultimately help transform our municipal wastewater flow and sewage sludge into more acceptable material for recycling and reuse.

All of these factors are influencing our policymakers and will increasingly be influencing the direction of our program.

As for the development of methods to make wastewater more acceptable to our citizens and to increase its use, there are many land treatment projects of an interesting nature that are underway in the United States, some of which you have visited. We are currently funding 337 land application or land treatment projects scattered among all but ten of our States, but most are in the water short States which are growing rapidly and supporting major agricultural activities. California has 69 of these projects: Florida 29.

I mentioned the Muskegon project. Those of you who were there know that it is a slow infiltration type of system, employing underdrains to test and collect the effluent, coupled with the cultivation of corn. Over a quarter million bushels of corn have been grown on formerly poor agricultural land, and sold to pay over one-third of the annual operating cost of the project.

One of the most important facts about the Muskegon project is that in treating over 27 million gallons of wastewater each day, it is able to effectively handle the toxic organic pollutants from paper mills and related industries.

Further, only 40 persons are required to manage the entire system, including the collection and pumping of sewage, operation of a laboratory, farm administration, maintenance, irrigation, drainage, and all the other requirements to operate a 4,000 hectare farm. The total net cost for treating the wastewater in 1977 was 25 cents per 1,000 gallons, about the cheapest wastewater treatment system in the U.S. Water is highly renovated by 98% removal of phosphates, BOD and suspended solids are reduced to 3 and 7 ppm, respectively. Various other land treatment systems are of interest.

Rapid infiltration systems in sandy, highly permeable soils: There are 10-12 such systems in the U.S. I would refer to the project in Tempe, Arizona, outside Phoenix. The Flushing Plains Project is being funded by the agricultural research service and EPA. There is particular interest in the system in this water short area because it seems capable of providing tertiary treatment at a significantly lower price than the conventional systems. It also appears to be removing the viruses and pathogens, necessary to potable water.

An overland flow system is being operated at Utica, Mississippi, which the Corps of Engineers is monitoring, the advantage of such overland flow systems is the ability to remove nitrogen, and it can be used on tight, clay soil where other land treatment systems are ineffective.

I realize all of these land treatment systems are operating in Europe; but, these were generally instituted to obtain water for farming. We are trying these systems with the primary goal of providing highly-renovated water, year round for human consumption. We hope to obtain reusable water, in short, potable water.

I understand you are planning to hold an international symposium on land treatment of wastewater. I further understand one of the protocols that was signed with a U.S. mission from the Corps of Engineers envisions your installation of an overland flow system in the Soviet Union to study its utility in colder climates. I will be examining the results you obtain from both of these initiatives, with a view to possible applications in our program.

In regard to the problems of sludge disposal and management, I know that many of you have visited the sludge composting project in Beltsville, Maryland, outside of Washington, D.C., jointly operated by the State of Maryland, the Department of Agriculture, EPA, and the Government of the District of Columbia. The internal heat generated within these composting piles appears to be sufficient to kill the pathogens; and further, the end product is an acceptable and an esthetic humus that can be easily handled and spread on the land with conventional equipment. This pilot operation handles up to 200 tons of filter cake sludge per day without the capital investment for buildings, using only portable equipment.

It has been so successful that major cities around the U.S. are adopting the technique, particularly since it promises to stabilize raw sludge without problems of odor. Such a system when used to handle about 600 filter cake tons of sludge per day, will require less than 15 hectares of land.

As for the more building and equipment—intensive advanced wastewater treatment projects, we currently have 421 underway which, very generally, use various systems for nitrification and tertiary treatment, independent physical-chemical treatment and so on.

I began with the statement that we are emphasizing systems that utilize reuse and recycling of wastewater as the cost effective solution. But as our great American poet of the 19th century, James Russell Lowell, once wrote "New Occasions Teach New Ideas . . ."

I believe we have reached a new plateau in our program, and will now be implementing new treatment technologies.

The future should provide many opportunities for sharing the experiences. I commend the strong efforts of my Soviet colleaques. ☐

Fundamentals of Creating Closed-Loop Water Supply Systems at Industrial Enterprises

By Alferova L.A., Nechaev A.P., Markov P.P. All-Union Scientific Research Institute "VODGEO"

In the Soviet Union year by year problems of the natural waters protection from pollution are getting the utmost significance. In the 10th Five Year Plan II milliards rubles will be spent on the solution of the environmental protection problem including 8 milliards rubles to be spent on the water basins protection from the wastewaters pollution. In particular, construction of treatment facilities with the total capacity of 48.2 millions cubic meters per day of wastewater and putting into operation recirculating water supply systems with the capacity of 150,000,000 m^3 per day of recirculating water are now on the planning stage. Average annual increment of the quantity of water in the recirculating systems will rise by a factor of 3 as compared to 1975. Calculating on 1980 the introduction of recirculating water supply systems will result in the water savings of about 200 cubic kilometers per year. However at the present-day state of the treatment technology the availability of treatment facilities at each industrial enterprise will not permit the complete prevention of water basins from pollution.

The most rational in the solution of the problem of water basins protection from pollution is the creation of closed-loop water supply systems at industrial enterprises involving the effluent reuse for technological and recirculating water supply, fresh water being taken from water sources mainly for potable water supply. Creation of such systems is not possible only at the expense of the wastewater treatment methods development or at the expense of the non-water processes. It is necessary to develop technological processes permitting maximum use of raw materials, the sharp reduction of wastes, maximum possible reduction of water consumption. It is also very important to develop both the rational schemes of industrial water supply involving reuse of water in technological processes and the methods of local treatment of the most polluted wastewaters with the sum of creating recirculating water supply systems within shops. In this case it is possible to reduce materially the quantity of wastewaters delivered to the treatment facilities located beyond the technological site. These treatment facilities receive wastewaters containing biodegradeable compositions which permits the reuse of the treated effluent in the systems of technological and recirculating water supply.

The main principles of creating the closed-loop water supply systems at industrial enterprises are the following:

1. Employment of non-water or consuming little water technological processess ensuring more complete use of raw materials. Air coolers, methods of dry gas scrubbing and non-water preparation of raw materials are being introduced on a large scale.

Introduction of air coolers permits not only to save large quantities of water but to reduce the wastewater volume. At present only in petrochemical and oil-refining indusries there were installed more than 2500 apparatus of air cooling. It is necessary to exclude the use of water for gas scrubbing without recovering and utilization of valuable components. Only in the iron and steel industry the employment of dry methods of gas scrubbing allows to reduce water consumption by 15-20%.

2. The right choice and location of miscellaneous industrial processes at an enterprise providing successive water reuse.

3. Improvement of technological processes which allows to reduce the quantity and polluting strength of wastewaters. For example, at nitrogen producing enterprises a wide-scale introduction of consolidated technological units involving the use and utilization of reaction heat permitted to reduce the specific water consumption in ammonia production by 67-70%, in nitric

acid production by 90-95% and in ammonium nitrate production by 67-70% respectively. Introduction of the one-stage method of divinyl production at petrochemical enterprises reduces the amount of wastewaters by a factor of 100. In monocorundum production the amount of pollutants in wastewaters may be sharply reduced provided that generated hydrogen sulfide is recovered from gas-vapour mixtures with the help of carbonic sorbents which can be used in the melting charge.

Regeneration of wasted acid and alkaline solutions is a very important problem. It will result in the sharp reduction of salts contained in wastewaters which results from the process of their neutralization.

4. Rational reuse of water in all technological processes and procedures and creation of closed industrial water supply systems. The development of physico-chemical methods of wastewater treatment providing reuse of effluents in the same operation and rational use of water in the most water-consuming technological processes such as washing of primary, semi-processed and end-products are of a special importance.

In this case the tertiary wastewater treatment is not needed and the removal from wastewaters of the components producing a negative effect on the quality of the product to be washed seems to be quite sufficient.

For example, an efficient scheme of water use in the synthetic fatty acids production developed by VNII VODGEO together with the Scientific Research Institute of Surfactants provides the acid concentration of wastewaters of 180–200 g/l. Treatment of such wastewaters by the azeotropic rectification method permits on the one hand to recover and obtain commodity low-molecular fatty acids such as formic, acetic, propyonic and butyric and on the other hand to reuse the effluent in the technological process. Thus a closed-look system of technological water supply was created on the basis of acid wastewaters. It increases the output of commodity acids by 12% and reduces the quantity of pollution evaluated by the COD value and entering the biological treatment facilities at a standard synthetic fatty acids producing plant from 27 to 2 tons per day.

Large amounts of wastewaters are formed at the vacuum vaporizers and vacuum distilling apparatuses where the volatile compositions are washed out from gases by water in barometric condensers. No doubt that it is more efficient to recover volatile compositions immediately from gas-vapor mixtures with the help of special adsorbents. For example, the principle scheme of the system of primary petroleum refinement installations allows sharp reduction of hydrogen sulfide discharge into wastewaters and the atmosphere. It also permits the increase of diesel fuel recovery from the barometric wastewaters.

5. The next principle is the classification of wastewaters according to the character and the total quantity of pollution as well as the development of the rational scheme of their treatment for reuse. The development of methods of wastewaters treatment from separate classes of organics with the account of their physical-chemical properties as well as the properties of their main concominant compositions is of a special importance.

For example, in accordance with the development of the authors of classification of wastewaters containing hydrogen sulfide, sulfur alcohols and their salts, organic sulfides and disulfides and produced in the process of sulfate pulp, artificial fibres, monocorundum production at the sufite petroleum refining, all sulfur compounds are divided into two groups and all wastewaters are divided into three categories. Separate methods of treatment were developed for each category of wastewaters taking into account the character of concominant pollutants.

6. Providing such quality of wastewaters entering the treatment facilities beyond the technological site which provides their treatment at these installations. Removal of biologically nondegradeable and toxic compounds from local flows of wastewaters prior to their splicing into the common flow, entering the treatment facilities located outside the technological site is the obligatory condition for creating closed-loop industrial water supply systems.

Optimization of water use provides a sharp reduction of the wastewater quantity and increase in their pollution. So physico-chemical methods of wastewater treatment have been widely used lately.

However, it will be wrong to reject the biological wastewater treatment completely. Each method must be used in those cases, when any other method is less efficient from the technological and economic standpoint. Profound investigation of the character and physical-chemical properties of wastewaters should preceed the use of one or another method. Our experience has shown that only a certain combination of methods may be optimum, so specialists must be good at finding a rational method and schemes of wastewater treatment for each case.

7. The quality of biochemically treated effluents should meet both sanitary and toxicological requirements for make-up water in recycling systems of industrial cooling. Either one of the methods or their combination may be used in order to achieve this purpose. Epidemiological safety of wastewaters is usually achieved by chlorination. Residual chlorine content equal to 1-1.5 mg/l after the contact time of 30 min. provides conditions necessary for desinfection of domestic-fecal sewage. Coliindex must not exceed the value of 1000.

Pollution of the atmosphere during the make-up of cooling recycling systems by treated effluents must be eliminated. Water drops splashing out of cooling towers must be minimum and hydro-aerosoles formed must not be toxic.

At present the researches carried on in the field of the sanitary and toxicological evaluation of treated domestic sewage, recycling cooling waters and hydro-aerosoles around cooling towers are being completed. As far as industrial wastewaters are concerned their toxicological investigations must be carried out for each case prior to giving the permission for their use as make-up water in recycling industrial cooling systems after appropriate treatment.

The latter problem is extremely difficult because of the prolonged toxicological tests carried out on animals. Development of the so called mutatest which can permit to evaluate the toxicity of treated effluents within the period of 2-3 days is one of the main tasks confronting sanitary inspectors.

At the Institute VODGEO conditions were investigated under which wastewaters of the City of Moscow can be used in through-out and recycling systems of cooling water supply. They contain 60% of domestic sewages and 40% of industrial wastewaters mainly discharged from machine-building plants. The investigations have shown that after treatment by the following scheme: mechanical treatment—biological treatment—tertiary treatment on grain-bed filters—chlorination they can be used in through-out water supply systems. Treated effluents used in recirculating systems of industrial cooling water supply should be conditioned: a) when blowing-off is envisaged they are treated in order to protect systems from biological foulings and carbonaceous deposits; b) effluents used in systems without blowing-off undergo additional treatment aimed at corrosion protection. Recycling waters are partially clarified from suspended solids. After such treatment municipal wastewaters are absolutely safe from the sanitary standpoint and can be reused in water supply and cooling systems of industrial enterprises. Beginning from

December 1975 treated sewages of the City of Moscow are used at a number of industrial enterprises in through-out and recirculating water supply systems as well as in a number of technological processes, for example, at an automobile plant in electroplating shops (for washing and stripping, in Hydro-wartex apparatus), in paint shops (in hydraulic valves of some chambers, phosphatic covering baths), in test shops (in Spriwax chambers, for washing of automobiles and in air-tests).

8. The next principle is the employment of wastewater desalination. Classification of wastewaters and development of a rational scheme of desalination are very important both for desalination and treatment of wastewaters. Removal of individual salts, return of treated wastewater and recovered salts back into the process, regeneration and reuse of brines—all this serves as an ideal solution of the problem.

Development of methods of analysis and investigation of chemical composition of wastewaters at all stages of treatment is the problem of special significance. Investigation of biochemically treated wastewater chemical composition is the most difficult problem. Information about chemical composition of various industrial effluents permits the generalization of data and forecast the quality of treated effluents depending on their initial characteristics and chosen methods of treatment.

Creation of closed systems of industrial water supply demands that scientific researches should be directed to the development of water economy systems rather than to the development of various treatment methods. It involves optimization of water use in all technological processes and operations, regeneration of wasted solutions, recovery of valuable components from wastewaters, development of the local effluents methods of treatment, creation of local closed systems of technological water supply, solution of all problems concerning final treatment of wastewaters, treatment of make-up waters recycling in the systems of industrial cooling, treatment of recycling water, sludges disinfection. This will promote development of industrial water economy systems within a very short period of time in regard to known methods of wastewater treatment. Problems which cannot be solved now or problems which solutions are not optimum can be revealed. In other words, objects of further investigations both in the field of general technology improvement and treatment technique improvement.

The following problems need to be investigated: obtaining highly efficient sorbents for tertiary treatment of wastewaters; survey of effective enzymes for wastewater oxidation by atmospheric oxygen being permitted to carry on the process at temperatures below 250°C; survey of effective enzymes for low-temperature incineration of wastewater sludges; creation of highly effective organic coagulating and flocculating agents; development of new mutatest for toxicological evaluation of treated effluents and aerosols.

Schemes of wastewater treatment involving treatment of both local and combined flows of wastewaters must be optimum from the engineering and economic standpoint. In this connection the development of mathematical models simplifying scientific researches and reducing the time necessary for determination of optimum schemes and operation parameters of separate units of the scheme acquires especial significance.

In some instances creation of closed water supply systems at industrial complexes or in industrial areas rather than at individual enterprises will prove to be the most rational. In this case treatment of wastewaters and final treatment of low contaminated effluents with the employment of hydrobotanical method may appear to be very effective in the South and in the middle zone of the USSR. This method permits the removal of both organic and mineral compounds from wastewaters. Institute VODGEO carried out investigations in the field of treatment of low-contaminated wastewater flow discharged from the industrial complex formed by eleven industrial enterprises including a tire plant, an artificial fibres plant and a plant for organic synthesis of synthetic rubber. In the first step of treatment, wastewaters come into contact with hydrocultures of higher aquatic plants in a channel, at the second step the contact takes place in a pond, COD of wastewaters is reduced from 90-180 mg/1 to 54-86 mg/1, BOD_{20} is reduced from 25-30 mg/1 to 6.5-14 mg/l, complete removal of zinc, copper, methanol, and oil-refinery products (about 50 mg/l in the influent) and almost complete removal of aniline, toluene and caprolactan is achieved.

Aquatic life of hydro-biobotanical treatment facilities has a pronounced tendency to increase in the number of species from beginning of the channel to the end of the pond, inhabited by a great number of hydrobionts and Daphnia Magna in particular. This indicates a successive reduction in wastewater toxicity up to the level required for water in sanitary reservoirs.

Treated wastewaters quality meets the quality of water used in recirculating systems of cooling water supply.

Thus solution of the problem of creating closed-loop systems of industrial water supply puts forward a number of new problems, introduction of these systems depends on their solution.

"The Closed-Loop Cycle for Industrial Wastewater The Future Pollution Solution*

By Dipl-Ing. William J. Lacy, P.E.

Introduction

When we view the world about us it becomes evident that a natural water cycle exists. A process engineering schematic of this cycle, or process, is shown in Figure 1. Very simply it consists of the use of solar energy to evaporate water from the ocean, whereupon it is condensed as rain by a space cooler. Hereafter it becomes available for use to man via the drainage avenues of our land surfaces, lakes, rivers, etc. During the period of returning to the sea, the waterways provide the circumstances for coagulation-sedimentation, and bio-stabilization of natural and man induced pollutants in the waters. In summary, the basic natural process is a three step process—a perpetual machine, a closed water management cycle.

The U.S. Department of Commerce has for years conducted a Census of Water Use in Manufacturing. (1) This is a major source of qualitative water use statistics in the U.S. The last four census show the extent, use of, and trends of water use by U.S. industries. Figure 2 reviewing the statistics of the most intensive water-using industries (cumulative water use equal to 90 percent of total industrial use, exclusive of Electric Power Utilities), the trends of usage are shown in Table I. It is apparent from the Table that the water reuse for all the U.S. industries and also for the big four major industrial users, has been increasing and greater improvement is possible.

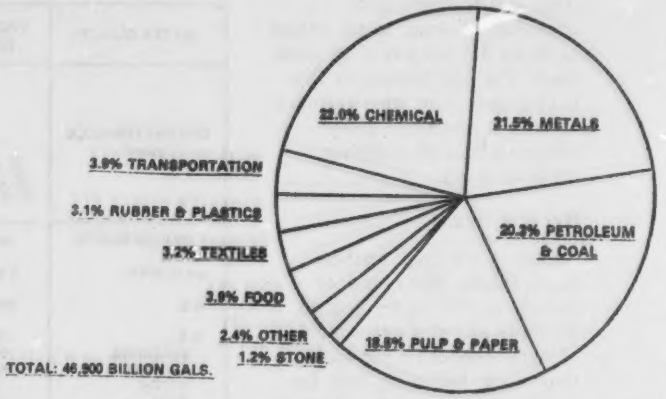

Figure 2
Industrial Water Use

INDUSTRY AND CENSUS YEAR		GROSS WATER[2] USE X 10^{12} GALS/YR	WATER INTAKE X10^{12} GALS/YR	PEPCENT OF GROSS CONSUMED	REUSE[3] RATIO
ALL –	1973	46.9	15.0	1.9	3.1
	1968	35.7	15.5	3.3	2.3
	1954	21.0	11.6	–	1.8
PRIMARY METALS	1973	8.8	4.9	1.1	1.8
	1968	7.8	5.0	4.0	1.6
	1954	4.9	3.8	–	1.3
CHEMICAL	–	11.1	4.2	2.5	5.3
	1968	9.4	4.5	3.2	2.1
	1954	4.3	2.7	–	1.6
PULP & PAPER	1973	8.1	2.4	1.2	3.4
	1968	6.6	2.3	2.7	2.9
	1554	4.2	1.8	–	2.4
PETRO REFINING & COAL PROC.	1973	8.2	1.3	1.4	6.3
	1968	7.3	1.4	3.0	5.1
	1954	4.2	1.2	–	3.4

[1] U.S. DEPT. OF COMMERCE CENSUS OF MANUFACTURES
[2] INCLUDING RECIRCULATED
[3] REUSE RATIO = $\frac{\text{GROSS USE}}{\text{INTAKE}}$

Table 1
Industrial Water Use Trends in the U.S.A.

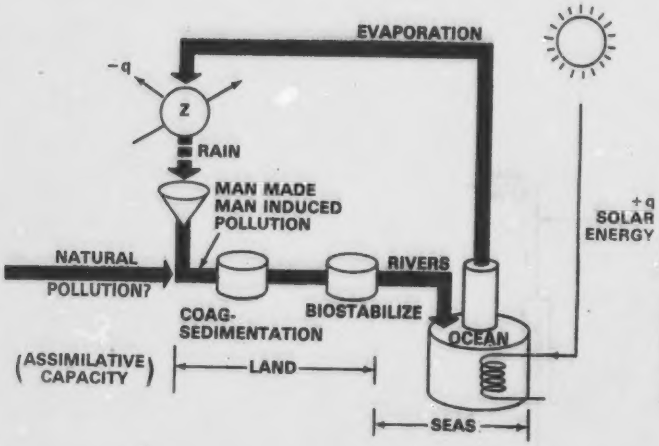

Figure 1
The Natural Water Cycle

		WATER INTAKE USE BY FUNCTION, %	
INDUSTRY GROUP	COOLING	PROCESS	BOILER FEED
ALL (U.S. INDUSTRIES)	67	26	7
PRIMARY METALS	74	22	4
CHEMICAL	80	15	5
PULP AND PAPER	30	64	6
PETROLEUM REFINING	87	6	7

Table 3
Industrial Water Use by Function

* Presentation at The US/USSR "Recycling Water Supply Systems and Reuse of Treated Water at Industrial Plants; Symposium Moscow, USSR September 12-16, 1977.

** Principal Engineering Science Adviser, Office Research & Development, U.S. Environmental Protection Agency, Washington, D.C. 20460

Also that industry is a consumer of water to the extent of about 3.3 percent of its gross need. The significance of this is that there is no physical need to have a discharge under circumstances of complete reuse of water.

Recycle-Reuse

Before proceeding further, multiple use, reuse, and/or recycle need(s) to be defined. Multiple use of water a method of reuse implies its use more than once, but each time for a different purpose; for example, the countercurrent use of water for successively dirtier applications, but never for the same applications, until it is no longer needed. This in contrast to a once-through use of water (used only once in any application.)

Recycle (also a method of reuse) implies using water over and over again for the same identical application from which it came. By this method, the total water intake of a plant, where reuse is practiced extensively, can be substantially less than a similar plant using water on a once-through basis.

Industrial Water Quality

Water use and needs in the manufacturing industries can be divided among three major functions: for cooling purposes, for process use, and for boiler feedwater used for steam production. (2) Table III shows the water intake by function for all and selected industrial groups. These are the makeup requirements for each function and do not reflect the extent of current internal water reuse which occurs within any one function. Obviously cooling water needs are greatest, followed by process demands and boiler feed make-up. This is a fortunate situation since the water quality requirements for these functions are, generally speaking, less critical for cooling, than for process, than for boiler feed.

To illustrate the point on quality, Table 4 is a summary of water quality characteristics of the various water functions for the major industrial users

WATER QUALITY	COOLING WATER (ONCE THRU)		PROCESS AND GENERAL INDUSTRIAL WATER						BOILER FEEDWATER
			IRON AND STEEL			PULP AND PAPER			
CHARACTERISTICS (ppm)	FRESH SOURCE	BRACKISH SOURCE	QUENCH AND GAS CLEAN	DM RINSE	CHEMICAL AND ALLIED PRODUCTS	KRAFT UN-BLEACHED	FINE	PETRO REFIN.	(150 PSIG) (PRIOR TO CHEM. COND)
TEMPERATURE °F	(b)	(b)	100	100	(b)	—	—	—	(b)
ph (UNITS)	5-8.3	6-8.3	5-9	—	5.5-9	—	—	6-9	7-10
S.S.	5000	2500	100	0.1	10000	(c) 100	(c) 10	5000	10
D.S.	1000	35000	(b)	0.1	2500	800	200	3500	700
CHLORIDE	600	19000	(b)	0.1	500	—	—	1600	(b)
SULFATE	680	2700	—	—	850	—	—	900	(b)
SILICA	50	25	—	—	(b)	100	20	85	30
IRON	(b)	(b)	—	—	10	1.0	0.1	15	1
HARDNESS	850	6250	(b)	0.1	1000	200	100	900	350
ALKALINITY	500	115	(b)	0.5	500	150	75	500	350
C.O.D.	75	75	—	—	(b)	—	—	1000	5
OIL	(d)	(d)	(b)	.02	—	—	—	—	—
COLOR (UNITS)	—	—	—	—	500	100	5	25	—
D.O.	SOME	SOME	SOME	SOME	(b)	—	—	—	2.5

NOTES: (a) REF: WATER QUALITY CRITERIA EPA•R•73•033•MARCH 1973.
(b) ACCEPTED AS RECEIVED.
(c) AS TURBIDITY.
(d) NO FLOATING OIL.

Table 4
Industrial Water Quality in Use (a)

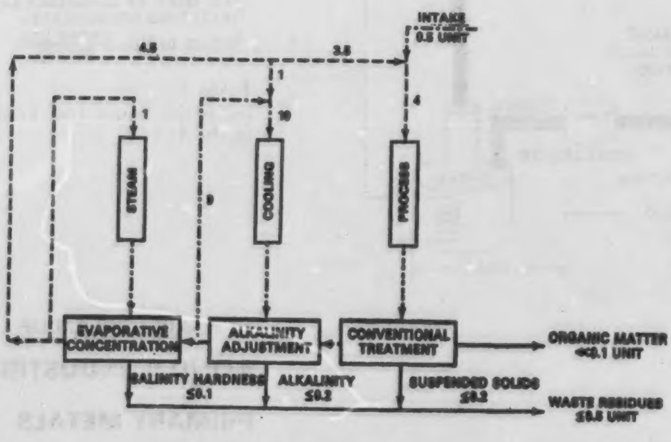

Figure 3
Reuse/Recycle Industrial Water System

as reported. (3) It should be evident from examining Table 4 that industry has use for low quality water and could use waters of various qualities. Further, that if we exclude the bacterial consideration that the quality criteria parameters are less stringent than those for desirable potable water. These are important points to note when planning an industrial water management system, since they would allow the reuse of water in a countercurrent manner for successively dirtier applications. In fact, combining reuse with a water recycle system (one that allows the use of the water over again for the same identical application from which it came) can close an industrial water circuit to the point of essentially "zero discharge." This latter concept is shown schematically in Figure 3. Here it is assumed all intake is for process use, that treated process effluent is reused for cooling water makeup, and that cooling water blowdown is regenerated for boiler feed-cooling—or recycle for process water makeup. The relative flows shown are in proportion to the intake needs of the various use functions as previously shown in Table 3 for all U.S. industries.

If the ratio of gross water to water intake is an index of reuse, the once-through system would have a reuse ratio of 1.00. The multiple use system would be 1.50, and the reuse-recycle system would be 15.00. In a total reuse system the ratio would be infinite.

In practice, this can never be achieved due to water consumption (evaporation and drift losses, leaks, etc.) and the final fluid blowdown requirements imposed by salinity buildup and sludge removals. Some water intake will always be necessary.

Rather than discuss economics with typical costs based on amount of water treated or on the specific processes employed it may be simpler to look at total cost. Water treatment costs are related to volume of water treated, amounts of ss, alkalinity, hardness, organic matter, dissolved salts removed. The controlling factor and their approximate cost of removal from a hypothetical waste waters system are shown in Table 2.

In poor water quality areas the total water recycle method may provide minimum cost for pollution control as these water supplies bring into a plant several of the same materials whose removal is required for use or discharge. The net effect is that more suspended solids, organic materials, and dissolved salts would be handled on a once-through basis than if only net increases due to internal (closed loop) plant functions were to be treated. This point should be kept in mind when industrial wastes pollution control plans are being made.

All this is fine in concept, but the question is will it be practical for industry to implement, in a realistic manner, closed water management systems by 1985 or soon thereafter. The answer to this is simply yes, but only if the technology is properly developed. Technology as referred to is meant to mean "a technical method of achieving a practical purposes" as Webster's Collegiate Dictionary defines it. In other words, technology does not mean can it be done—but rather can it be done in a *practical* manner.

Research and Development Needs

The R&D needs to achieve realistic "zero discharge" of water pollutants, for the diversity of industrial water problems are many. A detailed listing of needs is not practical to present at this time. However if the approach is "aero discharge" is related to intergraded supply and wastewater management then at least the major areas for R&D can be identified.

Figure 4 depicts a current water management system of a hypothetical self-sufficient industrial plant. It also shows various alternative possibilities to reuse-recycle water, to manage sludges (i.e. residues), and the general areas where R&D may provide for a better way to reduce water pollution external to an industrial plant.

A detailed study of the Figure should reveal that the previous system shown in Figure 3 is "built into" this more complex model as one alternative. It will also indicate the major industrial water use and handling activities (i.e. cooling, process operations, water treatment, and steam production) should be viewed individually for opportunities to improve pollution control performance and/or reduce pollutants, as well as in an intergraded fashion to conserve energy and duplicative treatment. For example in process operations, improved housekeeping, revised operating procedures, and process changes in themselves may produce significant gains in reducing water management costs while improving pollution control. Since most industrial water is for cooling purposes, R&D in cooling techniques, water quality limitations, corrosion control, and the effectiveness of the cooling process itself as a method of treating pollutants (other than heat) should be undertaken in great depth. The pay-off of R&D has always thereby allowed greater latitude or choices for accomplishing objectives. New and improved water pollution control methods are a likely fallout of R&D investigations when directed to the achievement of specific goals.

The challenge of achieving "zero discharge" from the major water use is primarily one best suited to the chemical engineering profession. The problems of the four large water users are not sanitary in the classical sense but rather chemical, or more specifically one of chemical separation of of pollutants in water to a desired level which will allow reuse or discharge if needed. Finally, one of optimizing and intergrading water conditioning and treatment steps to result in a minimum of operations.

This system also includes consideration for environmental factors other than water pollution control. These factors, also to be considered in the future, concern use of waste water for air and thermal pollution control functions and waste residue usage for heat and power production and/or water treatment (ash and sludges). However, even an ideal plant system will have a net discharge of waste material. In the system discussed, this includes excess ash from thermal power production and a wastewater blowdown of high salinity, hardness, and toxicity. These wastes may be blended for some beneficial purpose, to ease proper handling, or for controlled assimilation by the environment in appropriate disposal sites. These areas have to be given consideration as man proceeds to meet future environmental demands.

The industrial water management concept of closed-cycle operation to achieve "zero discharge" appears to be historically, economically, as well as theoretically, a sound approach to industrial pollution control. The excessive or unreasonable energy demands for industrial water pollution may be more conjecture than apparent fact. For it is difficult to conceive how a water conservational approach to pollution control, properly developed, would not also be energy conserving.

The R&D needs are many and challenging, and the long term need for water conservation in an industrially expanding world justifies resolving these needs.

Progress in water reuse and recycle is being made and promises to be practical from an overall water management cost point of view.

Selected Industrial Example of Reuse, others could be cited (for details see the appendix)

1. Chemical Industry
Reuse of chemical process water via external and internal recycling.

2. Steel Industry
Reuse of wastewater in a steel pickling plant by neutralization

3. Concrete Industry
Reuse of wastewater in a ready mixed concrete plant

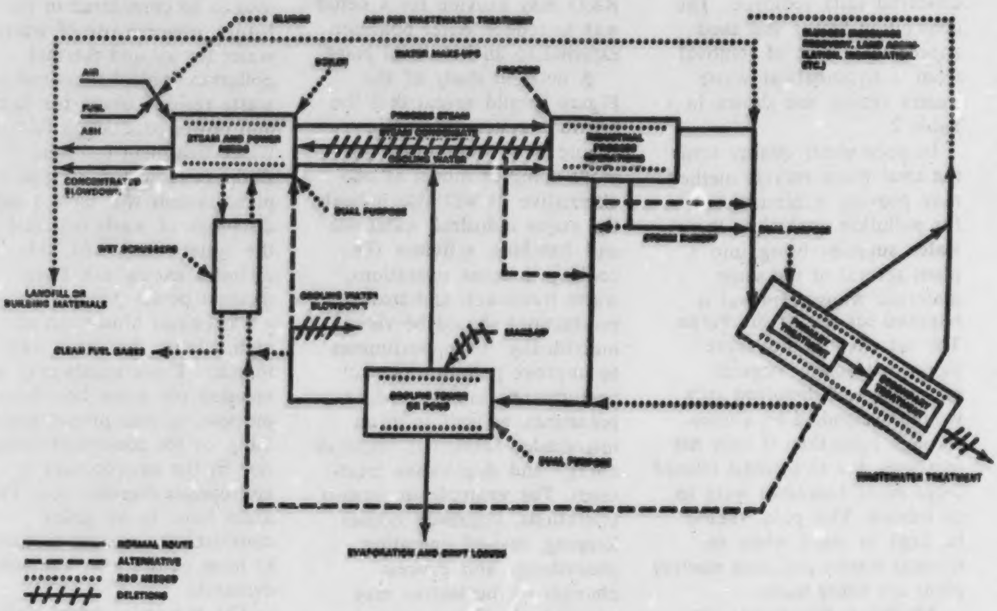
SLUDGE
ASH FOR WASTEWATER TREATMENT
WATER MAKE-UPS
BOILER
PROCESS
AIR
FUEL
ASH
STEAM AND POWER NEEDS
PROCESS STEAM
STEAM CONDENSATE
COOLING WATER
INDUSTRIAL PROCESS OPERATIONS
CONCENTRATED BLOWDOWN
DUAL PURPOSE
WET SCRUBBERS
LANDFILL OR BUILDING MATERIALS
COOLING WATER BLOWDOWN
MAKEUP
CLEAN FUEL GASES
COOLING TOWER OR POND
STORM RUNOFF
DUAL PURPOSE
SLUDGES DISPOSAL (RECOVERY, LAND APPLICATION, INCINERATION, ETC.)
PRIMARY TREATMENT
SECONDARY TREATMENT
WASTEWATER TREATMENT
DUAL PURPOSE
EVAPORATION AND DRIFT LOSSES
NORMAL ROUTE
ALTERNATIVE
R&D NEEDED
DELETIONS

Figure 4
Industrial Wastewater Management R&D Needs

4. Oil Refinery
Reuse of wastewater by treatment of an oil refinery effluent plus some comments on the subject
5. Pulp and Paper Industry
Reuse of wastewater from kraft pulping, bleaching and paper machines operations.

Future demands

Closed-loop industrial waste water and water systems are vitally necessary to maintain continuity in future industrial expansion. The huge water demands and high water usage growth rate of American industry cannot continue to rely solely on traditional water supply sources. Even in water-abundant areas, intake water supplies for industrial use are fast becoming restrictive. Trends toward water reuse have already been started and must be accelerated now—if an adequate base for future industrial expansion is to be provided.

Current and future environmental standards for waste water discharges are expected to increase the pressure on industry to reduce both the pollution discharge loads and the magnitude of effluent volumes in order to minimize environmental impact. Industrial water quality requirements for reuse are less demanding, as a general rule, than for municipal supplies. Accordingly, industrial water reuse should be technically and economically achievable earlier than comparable municipal water reuse systems.

Wastewater reuse is not only a resource conservation measure, but also a method of pollution control a step in tune with future demands. Adequate R&D activity in this area is the key to accelerating implementation of extensive wastewater reuse systems and, eventually, the total closed-loop cycle. The latter, with no effluent discharge, would comply with any quality standards now or in the future. ☐

UNDESIRABLE COMPONENT	ASSUMED METHOD OF REMOVAL	APPROX. COST, ¢/LB. REMOVED
SUSPENDED SOLIDS[a]	SEDIMENTATION	2
ORGANIC MATTER[b] (AS BOD)	BIOLOGICAL OXIDATION	2
TOTAL DISSOLVED SALTS[c] (INCLUDING HARDNESS)	MULTIEFFECT EVAPORATION AND SOLAR EVAPORATION	1.5
ALKALINITY (AS $CaCO_3$)[d]	ACID ADDITION	2

NOTES:
(a) PRIMARY TREATMENT AT 2.5¢/1000 GAL. WITH 200 PPM REMOVAL AND SLUDGE DISPOSAL OF 0.5¢/LB.
(b) SECONDARY TREATMENT AT 9¢/1000 GAL. WITH 400 PPM REMOVAL AND SLUDGE DISPOSAL AT 1¢/LB.
(c) FEED AT 2000 PPM, HARDNESS 200 PPM. ONE MGD PLANT WITH TOTAL COSTS AT $1.00/1000 GAL. AND NO CREDIT FOR PRODUCT WATER PRODUCED.
(d) TOTAL COST AT TWO TIMES CHEMICAL COST. SULFURIC ACID AT 1¢/LB.

Table 2
Water Treatment Costs

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Reuse of Chemical Process Water*

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External Recycling

At first glance, the chlor-alkali industry, the petroleum industry, and the pulp and paper industry seem to have little in common. They start with radically different raw materials, use entirely different manufacturing processes, and produce completely unrelated finished products. All three, however, use water that becomes contaminated by direct contact with chemicals and that must be disposed of in some acceptable way.

Electrolysis of the brine produces chlorine gas and caustic soda (NaOH) with hydrogen as a by-product. Since for every pound of chlorine produced, chemistry dictates that there is also produced about two pounds of 50 percent caustic soda solution in water. If the demand for chlorine is significantly greater than that for caustic soda over an extended period (as has occurred in the past), then unsold caustic soda inventories can build up to such a high level that some must be discarded. This would represent a serious pollutant.

The petroleum refining industry uses caustic soda in the production of gasoline and heating oil. It carries along with it process water from the chlor-alkali industry, the concentration is so high that refineries must normally dilute it with fresh water prior to use. Refineries mix the caustic soda solution with gasoline and heating oil to wash out undesirable sulfur compounds or to change their chemical nature to less objectionable forms. (The process is said to "sweeten" the gasoline.) After settling, the caustic solution is withdrawn and reused again many times. Eventually, however, it is no longer effective as a washing solution, and it must be disposed of as waste (or "spent") caustic. Since it contains dissolved organic acids such as phenols and mercaptans in addition to the caustic soda, it is an even more serious potential pollutant than when it left the chlor-alkali industry.

The pulp and paper industry uses large volumes of process water to make up chemical solutions that dissolve the glue-like lignin holding the wood fibers together. Most of this water leaves the pulping process as evaporator condensate that contains organic contaminants requiring treatment before discharge.

The recycle plant eliminates two potential sources of pollution from chemical process water:

1. Refinery waste caustics are no longer a disposal problem.
2. The likelihood of surplus caustic soda is reduced. More are able to use caustic as a treating chemical now because they have a reliable outlet for the waste caustic.

As a result, a typical gallon of process water beginning in the chlor-alkali industry would by-pass the effluent discharge and move on to the refining industry. It is joined by other process waters and exit the refinery as waste caustic. Now it no longer requires treatment and discharge, but rather is collected and shipped to the recycle plant. The value of the recovered products is usually sufficient to support a modest payment to the refineries, so part of that gallon of water winds up in the sodium sulfide solution sold as a raw material to the pulp and paper industry. After carrying chemicals through a series of pulp-making units, it is removed from the process as steam in an evaporator and condensed back into liquid water. Traditionally, it has been discarded as an effluent requiring treatment because of the presence of organic contaminants. More recently, however, pulp mills are recognizing the advantage of recycling this condensate back into the process. It reduces the amount of make-up process water needed, but, even more important, it eliminates a discharge stream completely and saves the cost of treating.

Internal Recycling

"Internal recyling", refers to the reuse of wastewater by the industry that generates it. The most essential prerequisites for a successful reuse program are: 1) an internal need for a sufficient volume of water to balance its production and 2) a process that can accommodate it.

Waste caustic solutions are collected from refineries and are used as chemical raw materials. A purification unit removes dissolved organic sulfur compounds extracted from gasoline and heating oil along with cresylic acids. Next, caustics are neutralized (with sulfur acid back then), springing the cresylic acids out of solution and causing them to float to the surface. This organic layer is withdrawn and further processed in a series of fractionation units where the various classes of cresylic acid products are separated and purified prior to marketing. Products include high purity phenol, cresols, xylenols, cresylic acid mixtures, and alkylated phenols. They are used as raw materials by other chemical and plastic producers in the manufacture of fire retardant vinyl plastics, nonflammable hydraulic fluids, electrical wire insulation, and molded laminants to name a few of the major end uses.

The plant water system is characterized by four types of effluent: a sulfate brine from neutralization, boiler water blowdown, cooling tower drawdown, and rainwater runoff. These were discharged into a brackish tidal stream.

Sulfuric acid neutralization was abandoned because it produced a sulfate brine that presented a disposal problem. By switching to hydrogen sulfide (recovered as a waste product from local refineries), the neutralization product emerged as sodium sulfide (Na2S) or sodium hydrosulfide (NaHS). This chemical is the active ingredient in the kraft process for making paper pulp and was a salable commodity. An evaporator was installed to remove some of the water to reduce the cost of shipping the solution to pulp mill customers. More recently, sodium sulfide has proven very useful as a precipitating agent to remove dissolved mercury and other heavy metals from industrial effluents (such as those from the chlor-alkali industry).

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* condensed by William J. Lacy

The net effect, as far as effluents were concerned, was to eliminate the sulfate brine and replace it with a smaller volume of evaporator condensate. This was essentially distilled water that sometimes carried over trace contaminants of sodium sulfide from the evaporator. It was an improvement over the sulfate brine, however, and reduced the effluent discharge load to an acceptable level. Rainwater runoff was eliminated as a contaminated effluent, the plant was surrounded with a series of dikes and curbs around all process and storage areas. Drains and sumps were installed within the diked areas to collect any accidental spills or leaks and pump the material back into the process. Any rainwater that falls onto these areas is also collected in a special tank and used as process water in such a way that all contaminants are recovered. The stormwater runoff system and tankage are designed to accommodate a 50-year statistical rainstorm. □

Wastewater Reuse in a Steel Pickling Operation*

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Two essentially identical pickling lines are operated by the Eaton Corporation, Engineered Fasteners Division, in Massillon, Ohio. Each pickling line contains a sulfuric acid pickling bath, a caustic-potassium permanganate solution for removal of smut after annealing, a zinc phosphate dip, proprietary neutralizing solutions, a rinse tank, and finally, a lime slurry. Alloy and high carbon steel wire is processed in the operations prior to drawing. Depending on the type of steel and its stage in the drawing operation, a wire coil is treated with various combinations of chemical solutions, rinsed, and coated with lime that is allowed to dry on the metal surface. Each coil of wire may be processed through the pickling operation as many as five times during the the sequence of drawing and annealing.

Discharge of contaminated water comes from the rinse tanks that utilize a combination spray and flowing rinse. Combined flow from the two rinse tanks averages 200 gpm. Major contaminants are the result of solution drag-out from the sulfuric acid and caustic-potassium permanganate tanks.

Alternatives for disposal of the effluent were complete treatment with discharge to a nearby stream, partial pretreatment and discharge to the municipal sanitary sewer, or wastewater treatment and recycle. Discussions with city officials confirmed that the local treatment plant was hydraulically overloaded and that discharge of large volume of additional industrial wastewater would not be acceptable. Effluent limitations for discharge to the stream were so stringent that treatment to an acceptable level would result in water of a quality satisfactory for reuse. The decision was made to install a system employing the water reuse principle.

First stage of the system is a 6,000 gal. equalization sump. This sump receives discharge from the rinse tanks and is equipped with an agitator thoroughly to blend incoming wastewater. Thirty minutes detention time is provided in the sump at the average flowrate of 200 gpm. Equalization diminishes pH variations in the waste stream through mutual neutralization of acid and alkaline materials, thus minimizing the need for chemical additions. Equalization also aids in removal of permanganate by blending ferrous salts carried out of the acid pickling tanks with the excess permanganate. Ferrous iron reduces the permanganate to manganese dioxide that precipitates and is removed in the settling process. At the same time, the iron is oxidized from a ferrous to a ferric state, making it less soluble.

Wastewater is pumped from the equalization sump into a neutralization tank. The neutralization provides 20 min. detention time and is equipped with an agitator. A pH controller proportionally controls the pumping rate of acid and alkali feed pumps to maintain a pH of approximately 7 in the neutralizer. Waste pickle liquor is used for the acid feed, and sodium hydroxide solution for the alkali. Excess permanganate, not reduced in the equalization sump, is reduced in the neutralizer by the addition of sodium bisulfite. The bisulfite pump is regulated by an oxidation-reduction potential (ORP) controller that senses the presence of excess permanganate.

From the neutralization tank, wastewater flows to a transfer tank and is then pumped to the clarifier. Aluminum sulfate (alum) solution, along with an anionic polyelectrolyte solution, is injected into the wastewater ahead of the clarifier to aid in flocculation and settling of suspended solids. The clarifier is a 24-ft. diameter solids contact type, with a turbine for internal sludge recirculation. Contact of incoming solids with recirculation enhances agglomeration of suspended particles and increases settling efficiency.

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* condensed by William J. Lacy

Clarifier wastewater overflows from the clarifier to a clear well. From the clear well the water is pumped through a pressure sand filter for final polishing and into a small holding pond. Water from the pond is pumped by a high pressure pump into a pressure tank which feeds the two rinse tanks.

Build-up of dissolved contamination of the closed-loop system makes it necessary to bleed-off a portion of the water in the system and replace it with fresh make-up water. In the Eaton installation, a conductivity controller monitors the dissolved solids level of the solution returning from the polishing filter. At a preset conductivity level, the controller opens a solenoid valve to allow bleed-off to the sanitary sewer. Bleed-off is approximately 10% of the total flow. City officials agreed to accept the bleed-off because it is small in volume and contains nothing detrimental to the sewage treatment process. Make-up water is provided by discharge into the pond of noncontact cooling water from the other areas of the plant. When additional make-up is needed, a low water level switch opens a solenoid valve, adding well water directly to the system.

It is necessary from time to time to dispose of sludge from the bottom of the clarifier—containing 1-2% solids and consisting mostly of ferric hydroxide. One option was dewatering of the sludge with a centrifuge or vacuum filter and removal to a sanitary landfill. Since the city sewage system was already processing solids, it was felt that the sludge could be discharged into the system without creating an overload. Samples of the sludge analysis, and discharge data were submitted to the city. City officials agreed to accept the low volume sludge discharge into the sewer system. The sludge is discharged periodically by a timer-controlled valve. The timer is set to maintain a predetermined sludge blanket level in the clarifier. Periodic filter backwash also is discharged to the sewer.

Control and monitoring of the entire treatment operation is done from a central control panel which contains electrical controls, instrumentation and recorders, and alarm systems. □

The Reuse of Wastes from the Ready-Mixed Concrete Industry*

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Waste Characterization

The waste stream from the ready-mixed concrete industry consists of returned concrete that for one reason or another has not been, or could not be, delivered to the customer and plant washwaters. If the returned concrete cannot be immediately used (typical methods of use are discussed below), it is often combined with the spent washwater into a single waste stream. This waste stream can be separated into four components: water (treated or untreated), coarse aggregate (gravel and/or stone), fine aggregate (sand), and cement fines, each of which can be recycled within the plant, sold, given away, or simply disposed of.

Returned concrete. On the average, 1 of 4% of total concrete production does not get delivered to the customer who ordered it. Reasons include: off-specification concrete, over-ordering, forms or other installations not ready, equipment failures, and rain, cold, or other weather considerations. The typical composition of a cubic yard of returned concrete is: coarse aggregate (sand), 1,275 lbs.; cement, 500 lbs.; and water, 300 lbs.

Since returned concrete usually has already been paid for by the customer, it does not represent a loss to the concrete company. However, returned concrete must be removed from the trucks before it hardens. To this end, it may simply be dumped on the ground as waste; it may be cast into products; or it can be recovered as sand, gravel, and other cement components in the washwater treatment system.

If returned concrete is to be used to maximum advantage, plans are usually made before the concrete is returned. For example, some plants keep lists of customers willing to accept concrete on short notice; others have molds available for the casting of simple objects such as blocks, benches, and highway dividers; and often there is a need for construction work

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* condensed by William J. Lacy

(such as yard paving) at the ready-mixed plant itself.

The latest treatment methods direct all wastewaters and solid wastes to useful ends. Two such systems have been chosen for discussion here. One system is designed for total inplant reuse of the waste components. The other is referred to as a symbiotic system because its output can be used as a feed for some other industry. Wastewater and returned concrete are passed through a screen to separate coarse aggregate. The remaining slurry of cement fines is agitated to keep the solids in suspension; then it is used in the mixing of new concrete. Separated aggregates may be reused in new concrete, or they may be sold.

Symbiotic system. Is a system designed for the recycling of all solid wastes, with zero discharge of wastewater. The basic element is a drag chain clarifier. Mixed aggregate and dried cement sludges are mechanically mixed to produce a material suitable for roadbed construction, floors, and driveways.

Depending on the degree of separation and the available market, aggregates are sold (or sometimes given away) for use as fill material, road and drive way bases, and almost any other use for which aggregates are normally sold. Cement fines, on the other hand, are so much altered from their original (i.e., prior to mixing) properties that they are no longer functional as cement. These fines have little economic value, though efforts are being made to find new ones. However, transport costs are high and, therefore, distance to the site of use is an important consideration.

Treated water is usually recycled and reused within the plant. Its alkaline nature may someday make it useful as a neutralizing stream for acid wastes from adjacent industries.

Systems that cleanly separate coarse and fine aggregate and reduce cement sludge to easily manageable or reusable forms are becoming available. The present incentive for recovery, and reuse is largely the result of disposal regulations, but in the future profitability may become an incentive. □

Treatment of Refinery Wastewaters for Reuse*

By Billy A. Carnes, Davis L. Ford and Sidney O. Brady
Engineering Science, Inc.

It has been estimated that the petroleum and petrochemical industry of the United States would require in excess of 12 billion gallons of water daily for once-through usage. Because of reuse-recycle, make-up requirements are slightly in excess of 20 percent of this amount with cooling water recycle accounting for approximately 90 percent of the reused water.

Today's refinery produces waste effluents; therefore, treatment processes are required for disposal and/or reuse-recycle. Recent legislation calls for "zero discharge" by 1983 and although this stringent requirement is not practical or necessarily beneficial for all plant locations, many inland refineries have already initiated bold water use policies. Compared with most industries, costs for complying with more restrictive water pollution control regulations should affect petroleum refining the least because of their comparatively high reuse ratio.

By 2020, all industrial reuse of 54 percent of total municipal and manufacturing effluents would meet the entire projected increase in industrial water requirements. Therefore, industry not only finds itself in a race against time to reduce pollution but also in a competitive market with other water users.

Contaminant Effects

The classification of pollutants into categories such as organics or inorganics has it deficiencies. In some cases, these contaminants cause similar problems, while in other situations, organics may be broken down to form inorganic residuals. Some of the TDS concentrations of 3000 mg/l are acceptable and 50 percent COD removal is achieved by employing weak anion resins, lime softening and finally weak cation resins. Silica removals are only achieved by using high basic anion resins.

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* condensed by William J. Lacy

Apparently, ion exchange is the most efficient hardness removal process based on water recovery. These data were developed from pilot studies on brackish well water.

Brine Treatment

The blowdown from any desalination process consists of a concentrated solution of the the salts contained in the feed. Methods, including dilution into flowing streams, deep well injection and solar evaporation have been considered for ultimate disposal of other brines.

On-site reduction of the brine to dry solids is possible through the application of current technology. Reportedly, evaporation is the only technically and economically feasible process for dewatering brines. Furthermore, multiple-effect evaporation followed by direct contact drying, exemplified by fluid-bed incineration, appears to be the most suitable process. For some wastewaters, fluid-bed drying alone may be acceptable.

Bicarbonate hardness must be removed to prevent scaling in the evaporator. Acidification and degasification of carbon dioxide will accomplish this. Calcium and magnesium removal are also required to prevent sulfate precipitation. Silica may also cause problems in the evaporator; therefore, it should be removed in the water pretreatment step. Sulfate scaling may be reduced by recycling a slurry of sulfate crystals throughout the evaporator to provide nuclei for growth. Although scaling problems can be overcome with direct-contact evaporators as opposed to multiple-effect, high thermal efficiencies cannot be reached, no converted water is produced and heat recovery is not possible.

Additionally, since one of the products of brine dewatering will be magnesium chloride, its cementing tendencies must be considered in the selection of a drying process. A fluidized bed dryer fulfills this requirement quite well.

Treatment for "Zero Discharge"

Treated effluents may be acceptable for reuse within the refinery; however, something must eventually leave the system whether in the form of a liquid blowdown, brine or dry solids. Common practice has been to maintain a recycle system in economic balance by wasting a portion of the recycle. However, as water becomes more scarce and disposal criteria more stringent, additional treatment will be employed to reuse the blowdown or remove the contaminants from the make-up supply.

To make the most of effluent reuse, a total systems approach must be pursued, which considers treatment of make-up, recycle, inplant treatment and effluent treatment. If "zero discharge" is the objective, demineralization processes must be employed at one or more points within the overall scheme. This immediately leads to *ultimate disposal problems for* salt brines or slurries. At this point, ion exchange is the most advanced form of demineralization, but reverse osmosis appears to have the most promising future.

Methods for concentrating demineralization blowdowns are certainly in an infant stage of development in the wastewater treatment field. However, a study by DOW indicates that a flowsheet is feasible using bits and pieces of current technology.

The DOW report proposes vertical tube evaporation followed by bed drying as the best candidate for transforming brines into a final dry salt product.

A candidate for an advanced refinery water management system is a scheme where both freshwater and stormwater supply the plant's make-up requirements. The only liquid effluents, except for drift, are sanitary wastewaters and ballast water. Filtration followed by reverse osmosis is proposed for treating the cooling tower blowdown to maintain zero discharge. Highly contaminated streams are contained within the stream generation facilities to conserve thermal energy and reduce organic contaminant concentrations. The treatment philosophy proposed here is a departure from conventional centralized effluent collection and treatment processes, normally designed for disposal rather than total reuse. The conventional approach has many disadvantages for it does not optimize the use of refinery heat, hydraulic pressure, inplant oxidation and adsorption or point source concentrated treatment. If "zero discharge" of refinery effluents is to be achieved; these principles must be adhered to and conventional "treat and dispose" effluent management discouraged. □

An Overview of Water Reuse Potential in Pulp and Paper Manufacturing*

By Harry W. Gehm
Wapora Inc.

Kraft Pulping

The kraft process with its highly efficient recovery system has lent itself well to water recirculation. Process improvements in pulp washing and refining and in the evaporation of spent liquors, allowing condensates to be reused, have lowered the fresh water usage to a point where kraft pulp mills can be built to operate with less that 10,000 gallons per ton of product. While this low level is difficult or impossible to reach in older operations. these too have made substantial reductions in fresh water usage.

It appears that the limit of internal water reuse in kraft pulping is approached in modern mills and that further recycling will be dependent upon external effluent treatment. This conclusion is supported by papers by associates of the Swedish Steam Users Association who studied the unit processes of the kraft pulping and recovery system.

Economic limits for pulp washing systems have been established in relation to sewer losses. Condenstate losses were the subject of investigations including the improvement in their quality achievable by steam stripping. A rundown on the entire process on the basis of unit process capacity vs. losses which also supports this contention.

It can also be concluded that external treatment of mill effluent can extend reuse and reduce the process water requirement to a very high degree. However, streams rejected from such treatment will remain to be disposed of.

Kraft Bleaching

Excellent progress has been made in recycling water in the kraft bleaching process as well as in reducing the quantity if process water is used. Reuse of the weak effluents from the latter stages of bleaching in the initial chlorination and caustic extraction steps has accounted for the former and improved washing techniques in the latter. The quantity of water required depends upon the degrees of bleaching and the number of stages employed but, for example, the quantity of water employed in a five stage bleachery can be reduced from 30,000 gallons to as low as 10,000 with little difficulty. It has been suggested by Reeves and Rapson that such effluents be further reduced in volume and disposed of by addition to the kraft recovery systems. Chlorides would be removed by crystallizing sodium chloride from the white liquor. The recovered salt would be employed to produce chlorine and alkali for use in the process.

Appreciable recycle of bleachery effluents will depend largely upon external treatment. Methods for accomplishing this by removal of color, BOD and COD by lime precipitation. Further removal of dissolved organics can be achieved by biological oxidation and activated carbon adsorption. Chloride reduction can be accomplished by ion exchange. Costs for the removal of the dissolved organics are estimated to amount to somewhat less than three dollars per ton of pulp bleached to produce a water suitable for limited reuse in the bleach plant but not the pulp mill.

Oxidative pulp-bleaching could conceivable lead to a system discharging very low volume effluent streams. However, development of a commercial size plant applying this technique is still under study.

It can be stated that as in kraft pulping, further appreciable water recycling is contingent upon external water reclamation rather than additional in-plant alterations or unit improvements.

Paper Machine Waters

Spent process waters form the manufacture of the major unbleached kraft pulp products namely linerboard, wrapping and bag papers can be readily returned to the pulping process after passing through a vacuum filter type save-all. This accounts to a considerable degree for the low effluent volume from mills producing unbleached kraft mills manufacturing fine papers have been unable in most cases to recycle machine water to the pulping or bleaching operations due to the presence of dispersions and other paper making additives remaining after the usual clarification processes. Hence, bleached kraft fine paper mills frequently require from *32,000* to 40,000 gallons of water per ton of product. Assuming that 12,000 gallons of this is diverted to bleaching, then 20,000 to 28,000 gallons per ton is employed in pulp and papermaking as compared to 10,000 to 12,000 for unbleached kraft pulp and paper manufacture when good conservation practices are in effect.

Presently, extensive studies of the problem of reuse of the white water from fine paper manufacture in both the pulp and papermaking processes is underway in the industry.

Conclusions

It can be concluded that the pulp and paper industry has made considerable progress in recycling process water particularly in respect to kraft pulping, bleaching and papermaking which are responsible for a very large percentage of the total paper produced in the United States. Research and development efforts are directed toward further reduction in process water usage and effluent volume. However, it appears that the limit is being approached and that the application of external treatment water reclamation is likely to account for the greater portion of further progress in this direction.

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* condensed by William J. Lacy

Industry interest in applying water reclamation has been aroused through research development and demonstration projects as well as by recent legislation looking toward drastic reductions in effluent streams. While the panacea of effluent elimination is to a large extent obviously not achievable in complex chemical process industry, a projection of present activity in both technical and pollution control enforcement directions will lead to a considerable increased degree of process water reclamation and reuse. ☐

WaterReuse in Petroleum Refining*

By J.K. Rice
NUS Corporation

Since dissolved inorganic salts *are in final analysis*, the greatest potential disposal problem is every pound not brought in to the refinery is a pound that does not need to be disposed of. Rain runoff from the padded areas of a refinery is a source of low dissolved solids water that has generally been ignored as a source of makeup water. Collection, impoundment, and minimal treatment furnish a high quality makeup water without adding to disposal problems.

In summary, water reuse in a refinery to be effective and economical requires a thoroughgoing analysis of the quality of wastes at every point in the refinery with a concurrent establishment of the quality of makeup required for water utilizing processes. Selection of appropriate chemicals for corrosion and deposit control, appropriate equipment and material of construction specifications, all can allow a local reuse of water with minimum treatment within sections of the refinery. The end result is a greatly sectioned refinery. The end result is a reduced volume of highly concentrated waste amenable to total evaporation and disposal at acceptable costs if such is ultimately required: in other words, complete reuse.

Usage of Purified Waste Water in Refinery Circulating Water Systems.

By E.G. Ioakimis, K.Z. Saifutdinov, A.K. Yefimova, Bashkirian Scientific Research Institute of Petroleum Refining (USSR)

Circulating systems provide water for all the technological processes of primary and secondary crude distillation as well as for some petrochemical processes which have found application in petroleum refineries.

As make-up of circulating systems serves largely river water, groundwater is being used in insignificant amounts. Most petroleum refineries exhibit suspended solids in freshwater ranging from 10 to 70 mg/1. The BOD$_5$ value showing the pollution degree with organics varies between 3 and 22 mg O_2/1. The salt content of fresh sweet water ranges from 80 to 770 mg/1(dry residue). .

Qualities of circulating water at various plants vary over the following ranges:

suspended solids	10 to 90 mg/1
oil products	15 to 50 mg/1
BOD$_5$	15 - 60 mg O_2/1
total solids	200 - 1000 mg/1

(when using sweet water).

Specific consumptions of fresh sweet water in modern petroleum refineries with a high water circulation rate average 0.5 m^3 and 1 m^3/ton of crude processed for fuel and fuel-lubricating oil schemes, respectively. Specific consumptions of circulating water for the above types of refineries are 13 and 21.5 m^3/t, respectively, water use percentages amounting to 92 and 96%. Consumption values largely depend on quality of crude oils and the degree of their processing.

Circulating water systems that have found wide application at petrochemical and petroleum refinery plants greatly contribute to reducing industrial pollutants in natural water sources. However, the efficiency of this method for environmental pollution abatement is lowered by some specific factors, the main of them being as follows:

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* condensed by William J. Lacy

1. Evaporative cooling (mainly in cooling towers) contributes to salt and nonvolatile matter concentration in circulating water and simultaneous evolution of dissolved gases and lower boiling organics from water that are air pollutants.

2. Increasing salt and foreign matter concentrations in circulating water intensifies corrosion, scale-and-sludge formation in heat exchangers.

3. Large circulating water discharge to industrial sewers (bleeding of circulating water systems).

In the USSR petroleum refineries the following main trends in the improvement of circulating water supply are now observed: maximum use of air cooling and development of circulating water systems without bleeding.

Over the past ten years apparatuses of air cooling have found wide application at all the technological plants, and this tends to reduce circulating water consumption at these plants.

The forecast of the future water consumption is based on the assumption that 60-70% of the circulating water that is used for cooling petroleum products heated at least to 50-60°C could be transferred to air cooling. The remaining 30-40% of the water should be left in the circulating system for aftercooling the air cooled petroleum products.

The consumption of circulating water for cooling is known to depend on the condition of heat transfer surfaces which in its turn depends on the performance characteristics of the above water. The studies have shown that with no water treatment the circulating water exhibits the following technological properties:

corrosion rate 0.2 to 1 mm/yr
scaling rate 3000 to 6000 g/m^2.yr
biological growth 8 to 25 g/m^2.d .

According to the USSR standards, corrosion rate should not exceed 0.1 mm/yr, scaling rate 2200 g/m^2.yr, biological growth 1.7. g/m^2d. The attainment of the desired technological properties of the circulating water requires its conditioning. Some petroleum refineries remove suspended solids from fresh water through filtration, mainly with the use of pressure and gravity sand filters, which prevents the inflow of large amounts of river silt (especially over high water periods) into the circulating system.

Until recently, acidifying, phosphatization, chlorination, and the addition of blue vitriol were considered to be the main methods of the circulating water treatment.

As experience has shown, the water stabilization treatment does not sufficiently protect coolers and condensers from corrosion and scaling. Besides, the phosphatization intensifies biological growth in the circulating water systems, necessitates bleeding and leads to additional contamination of receiving waters with phosphates.

It is necessary to create conditions for the circulating systems to operate with no bleeding. However, this type of operation contributes to the increase in salt concentrations of the circulating waters and to the intensification of corrosion and scaling processes. All this necessitated the development of a more efficient method for the complex treatment of circulating cooling water. The scheme of such a complex treatment has been developed in BashNII NP, and now it is included in the designs of the reconstruction of operating water systems and the construction of new ones. In addition to oil traps, cooling towers and pump stations these systems include filtration, inhibition, and chlorination plants.

To clean all the fresh water from suspended solids in high water periods and a portion of circulating water (10% of an hourly flow rate) from suspended solids and petroleum products, quartz sand and petroleum coke pressure filters are used (filter bed depth 1 m, particle size 0.5 to 1 mm, filtration rate 8 m/hr). It is possible to use other types of filters as well.

The IKB-4 is recommended as a corrosion inhibitor, which makes it possible to reduce corrosion and scaling rates in heat exchangers on the average by 80%.

As a rule, chlorine is introduced into the cooled water in summer. During the operation the chlorine dose is established with due regard to the fact that chlorine residual content after the most remote exchanger should not exceed 0.2 mg Cl_2/1. Simultaneously blue vitriol is introduced into the hot water (once per 7 to 10 days), the dose being 4 mg Cu/1 based on an hourly water flow rate.

Such a complex water treatment provides purity, normal heat exchange in heat exchangers, and considerably reduces cooling water consumption.

The forthcoming transition to operating water circulating systems without bleeding necessitates the standardization of water qualities. The recently developed standards consider a remarkable increase in salt concentration (up to 2000 mg/1) of circulating water when operating circulating systems without bleeding compared to the present level (200 to 1000 mg/1).

Over the past 10 years, to reduce the bleeding as well as the fresh water intake, both operating plants and those under construction envisaged a maximum use of the treated industrial and storm runoffs.

An experience has shown that when using mechanically treated industrial and storm runoffs, the circulating water is largely contaminated with dissolved biodegradable organics, BOD total reaching 100 to 180 mg O_2/1. Cooling towers as well as heat exchangers prove to be silted due to an intensive biological growth and need frequent shut-downs for the purpose of cleaning. Therefore, most refiners have given up the idea of using mechanically treated wastes and changed to a fresh water make-up.

As results of pilot plant investigations in BashNII NP have shown, one-stage activated sludge treatment of industrial and storm runoffs originating from petroleum refineries makes it possible to reduce BOD total to 10 mg O_2/1. The biochemical treatment of industrial and storm runoffs is performed without dilution with domestic wastes, with an aeration period of 6 hours. Activated sludge concentration is maintained at 2 to 3 g/1, oxidation capacity of air tanks being 900 to 1000 g/m^3. day. Phosphorus is added as a biogenous element (up to 3 mg/1). There is no need to add ammoniacal nitrogen as these salts are present in wastes. Biochemical treatment effluents fully meet the standardized circulating water quality.

As it was found during the pilot plant investigations, industrial and storm runoffs that underwent biochemical treatment improve technological properties of the circulating water. They reduce the corrosion and scaling rates by 35 and 65% respectively, in comparison to the mechanical treatment alone.

A valuable experience in the biochemical treatment and reuse of industrial and

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storm runoffs in the Polotsk refinery confirmed the validity of our recommendations. At the same time it has been established that under large-scale conditions suspended solids are observed to be brought out from secondary settling tanks (over 25 mg/1), that is the treated wastewaters need an aftertreatment before their recirculation. For this purpose it is quite possible to use granular or mesh filters.

Sand filters with filtration rates of 10 m/hr are most efficient in aftertreatment operations (activated sludge removal 93 to 97%).

When operating filters, a progressive biological growth is observed leading to a decrease in filtration rates. To prevent this biological growth, a periodical treatment of filter beds with chlorine water is envisaged.

The recirculation of biochemically treated industrial and storm runoffs makes it possible to considerably reduce the fresh water intake, not excluding it completely, however, at the present circulating water flow rates.

In some areas with a bright outlook for the construction of new refineries, the lack of fresh water is felt. Hence, we are faced with an urgent problem of using other sources for the industrial water supply such as urban domestic sewage.

As one can see from the data of Table I, where the quality of treated urban sewage is shown its salt content varies over the wide ranges. High salt contents are peculiar to cities where industrial wastes are discharged into the urban sewers. The urban runoffs may be used in refinery circulating water systems after they have been aftertreated to remove suspended solids and if their salt content does not exceed 500 mg/1.

Pilot-scale investigations performed by BashNII NP have shown that corrosivity and scale formation ability of biochemically treated urban runoffs used as make-up water for circulating systems are somewhat higher than those of biochemically treated industrial and storm runoffs alone.

However, methods of circulating water treatment are almost the same for using both the treated domestic sewage and industrial-storm runoffs as make-up.

The salt composition of urban runoffs in the USA and the USSR is almost the same. The average phosphate concentration of the USSR biochemically treated domestic sewage (4mg P_2O_5/1) is eight times less than in the USA, therefore, the problem of phosphates removal from this sewage is not so urgent in our country than it is in the USA.

However, we need an industrial experience in the use of these wastewaters because they contain little quantities of aluminum, phosphorous, and silicon salts which being concentrated in the circulating water may interact to form compounds of low solubility.

The application of biochemically treated urban sewage as make-up of circulating systems will create a petroleum refinery not consuming fresh water and, therefore, independent of natural water sources.

In the future, application of make-up water from outside will be diminished because of decreasing of circulating water flow rates. It is due to the fact that half of refinery industrial and storm runoffs is composed of oil processing effluents (technological condensate flows, industrial and storm runoffs) and of wastes from outside sources (oily wastes—heat and power plants, steaming units, garages, laboratories, etc.). The application of these waste waters makes it possible to completely meet refinery make-up water requirements, with much lower circulating water flow rates.

As the salt composition of the circulating waters with no bleeding depends on quantity of dropwise carry over in the cooling towers, the use of improved cooling towers may result in higher equilibrium salt contents of the circulating water which are in excess of standard ones. In the future, complex treatment of water may be improved by its partial desalting. □

No.	Quality	min.	max.	mean
1.	Oil products,mg/1	3.5	24	11.7
2.	Suspended solids,mg/1	6.3	46	29.3
3.	Chlorides,mg / Cl'/1	14	244	120
4.	Sulphates,mg SO_4''/1	22	314	135
5.	Phosphates,mg P_2O_5''/1	1	25	4.2
6.	Nitrates,mg NO'_3/1	0.02	6.5	1.97
7.	Ammoniacal nitrogen,mg/1	1.6	37	12.9
8.	Total salt content,mg/1	323	1180	645
9.	Carbonate hardness,mg-eq/1	2.4	6.8	34

Table 1
Quality of Urban Domestic Sewage in the USSR

Recycling - Key to One Steel Mill's Pollution Control Program

By Eugene J. Peltier, Donald F. Cairns, and James C. Buzzell, Jr.*

Recycling proved to be a key element in the water pollution control program at Granite City Steel Division of the National Steel Corporation. This mill is a medium sized, integrated facility producing flat rolled steel products, and is located in Madison County, Illinois, just north of St. Louis, Missouri. As of July 1, 1977, Granite City Steel completed the latest step in its water pollution control program by placing a wastewater recycling system into operation. With this step the Company is able to meet both its immediate and long-range water pollution control goals.

Background

Granite City Steel manufacturing facilities include a coke plant and blast furnace facility and, on a separate tract of land, the steel works. Wastewaters originate from the following major production facilities: by-product coke plant; two blast furnaces; sintering plant; basic oxygen furnace (BOF) shop; blooming mill; 80-inch hot strip mill; 72-inch hot rolled coil processing and slitting lines; continuous coil pickling line; 56-inch, four-strand, cold strip reducing mill; three continuous galvanizing lines; batch pickling unit; and steam generating facilities.

The mill currently uses approximately 72 million gallons of water a day (mgd) , most of which is withdrawn from the Mississippi River. Ranney-type wells are available for supplemental uses when needed. Municipal water is used for the potable supply. Mississippi River water is pumped to a 10-million-gallon reservoir for distribution throughout the plant. Approximately 8 to 10 mgd are lost through evaporation and other losses so that the net discharge from the mill is about 62 mgd. In-plant oil/water and water/solids separation units provide primary treatment for the wastewaters associated with the byproduct coke plant, blast furnaces, BOF shop, blooming mill, hot strip mill, cold strip mill, and miscellaneous other operations. The mill long practiced extensive water reuse in various departments, but did not provide overall recycling. The treated effluent flows into Horseshoe Lake, a 2200-acre ox-bow lake that was, in prehistoric times, a section of the Mississippi River, and thence to the Mississippi River via a man-made drainage channel.

The previous major water pollution control step was taken by Granite City Steel in 1965, as described by Cairns (1). A 350-acre stabilization lagoon system was designed and constructed; one cell of the lagoon system provided 3.5 days detention for the wastewaters from the steelworks area, and the other cell provided approximately 10 days detention for the flow from the blast furnace area. This secondary treatment system has functioned as designed since 1965 with very few problems. Table 1 provides a comparison of the 1965 values reported by Cairns with the 1974 average values for the principal pollutant parameters. The 1974 data provided the basis for the design of the subject project. Table 1 illustrates two important aspects of the total water recycle and pollution control program. The first is that the stabilization lagoons have continued to function as they did in 1965, producing an effluent of consistent good quality. The apparent increases in the 1974 phenols and cyanide values may be due to the use of improved analytical techniques in recent years. Both parameters are effectively reduced by the lagoons, and the effluent levels remain below the desired concentrations. Influent levels in the Mississippi River water are approximately the same as the lagoon effluent levels for these two parameters.

Table 1 also shows that the overall quality of the lagoon effluent does not differ greatly

		Intake Water (Mississippi River) Averages		Lagoon Effluent * Averages	
		1965	1974	1965	1974
Suspended solids	— mg/1	62	65	18	16
5-day BOD	— mg/1	8	3.4	5	4
Oil & grease	— mg/1	5	5	5	5
Ammonia-N	— mg/1	1	0.5	3	2.8
Phenols	— mg/1	0.010	0.013	0.005	0.016
Cyanides	— mg/1	0.005	0.016	0.002	0.016
Zinc	— mg/1	..	0.16	..	0.26
Iron	— mg/1	..	3.5	..	3.9
Sulfates	— mg/1	..	50	..	85
Chlorides	— mg/1	..	22	..	105
Temperature	— °C	..	17.6	..	18.9

* Gross values, i.e., without deduction of background concentrations from the Mississippi River water intake.

Table 1
Comparison of Mill Intake Water with Stabilization Lagoon Effluent

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* E. J. Peltier is a consultant to Sverdrup & Parcel and Associates, Inc. of St. Louis, Missouri; D. F. Cairns is Vice President, Granite City Steel Division of National Steel Corporation; J. C. Buzzell, Jr. is Chief Engineer, Environmental Division of Sverdrup & Parcel and Associates, Inc.

in many respects from the intake water, illustrating the effectiveness of the overall Granite City Steel wastewater treatment system in removing net additions by the steel mill. Some parameters are consistently reduced by passage of the water through the mill, e.g., suspended solids. Other parameters show little or no net change between the intake and the lagoon effluent, specifically, BOD, oil and grease, phenols, cyanide, and total iron. The parameters that are increased are ammonia, sulfates, chlorides, and temperature.

Since the stabilization lagoons were placed in operation in 1965, much activity has occurred in the regulatory requirements for water pollution control at both the state and federal levels. More stringent effluent limitations and water quality standards were adopted by state and federal authorities for the waters of the state. Granite City Steel undertook steps to define its legal responsibilities under the new regulations as they were developed in the late 60's and early 70's. At the same time, the Granite City Steel Mill and Sverdrup & Parcel undertook a series of studies of means to upgrade and improve the mill's water pollution control system. These studies were part of the mill's overall environmental quality program.

It was finally determined that, despite the overall fine performance of the stabilization lagoon system, additional steps would be required to meet the new regulations as interpreted by the authorities. As noted previously, Horseshoe Lake receives the Granite City Steel effluent. This Lake is covered by water quality limitations of the State of Illinois Pollution Control Board. Despite its relatively shallow depth, approximately 4 feet, the Lake provides some year-round recreational use and some commercial fishing. The area around the stabilization basins is controlled by Granite City Steel, in its natural state, and is a wildlife refuge. The State has started to acquire shoreline land and convert the Lake and its immediate surroundings into a state park. For this reason water quality standards instead of effluent limitations were used as the goals in development of the new treatment program.

In evaluating the performance of the stabilization lagoon system over the 1965 to 1974 period, it was determined that four parameters would control the design of the new treatment facilities. The four parameters were phosphorus, suspended solids, iron, and ammonia-nitrogen. The stabilization lagoons provided adequate control of the other important pollutant constituents in the mill discharge.

Table 2 provides a comparison between the Illinois water quality standards for the critical parameters and the average and maximum values during 1974 in the lagoon system effluent.

		Water Quality Limits	Lagoon Effluent—1974 avg.	max.
Phosphorus	— mg/l	0.05	0.07	0.21
Suspended solids	— mg/l	*	16	34
Total iron	— mg/l	1.0	3.9	12.4
Ammonia-N	— mg/l	1.5	2.8	7.4

* Daily average concentration allowed by NPDES permit—12 mg/l.

Table 2

Illinois Water Quality Limits and Stabilization Lagoon Effluent Critical Parameters

Approach

Several alternative water pollution control programs were evaluated, including removal of the discharge from Horseshoe Lake to another outlet. Prior to 1965, the Lake periodically dried up during drought periods, and it was recognized that removal of the discharge would seriously reduce the utility of the Lake as a recreational asset. It was necessary to consider leaving the Lake, however, because of the water quality standard for phosphorus. At this time, there is no demonstrated technology by which the phosphorus content of the Granite City Steel mill effluent could be reduced to 0.05 mg/1. Ironically, the mill does not add phosphorus. The effluent reflects the levels in the intake Mississippi River water.

Because Horseshoe Lake is normally very turbid due to wind mixing, algal blooms do not occur, and phosphorus is not a critical element in the Lake's ecosystem. In light of this, plus the technical problem of removal, the Pollution Control Board granted a variance to Granite City Steel permitting discharge of phosphorus at previous levels. With this obstacle removed, it was possible to include continued use of the Lake as a receiving water in the pollution control programs under consideration.

Of the several alternative approaches evaluated, those involving recycle of the stabilization lagoon system effluent to the mill reservoir were the most attractive from the standpoint of treatment system design. The reduced volume of water to be treated would result in proportionately reduced costs for the tertiary stage treatment facility prior to discharge to Horseshoe Lake.

An evaluation was carried out to determine the blowdown volume necessary to control the buildup of materials in the recycled water. Such materials could impact the system in three ways: 1) the concentration of a specific parameter could be too high in the effluent; 2) the total dissolved solids limitation for the effluent could be exceeded; and 3) materials, e.g., calcium, could be problems in boiler water systems, cooling spray nozzles, etc. in the manufacturing areas. The minimum required blowdown volume was determined to be 25 mgd to control effluent concentrations of over 20 chemical constituents under extreme loading conditions. The recycle flow would then be 37 mgd with 35 mgd intake from the Mississippi River and an evaporation loss of 10 mgd. The basic system is shown schematically in Figure 1.

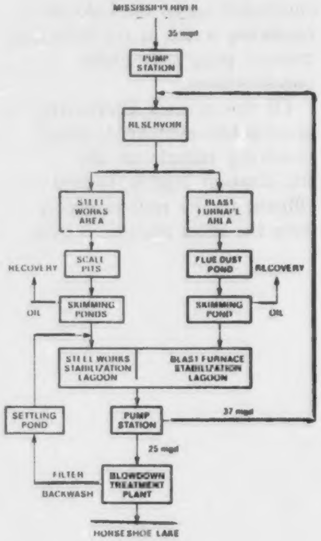
MISSISSIPPI RIVER
35 mgd
PUMP STATION
RESERVOIR
STEEL WORKS AREA
BLAST FURNACE AREA
RECOVERY
SCALE PITS
FLUE DUST POND
RECOVERY
OIL
SKIMMING PONDS
SKIMMING POND
OIL
STEEL WORKS STABILIZATION LAGOON
BLAST FURNACE STABILIZATION LAGOON
SETTLING POND
PUMP STATION
37 mgd
25 mgd
FILTER
BACKWASH
BLOWDOWN TREATMENT PLANT
HORSESHOE LAKE

Figure 1

Schematic Water Use and Wastewater Treatment System at Granite City Steel (New facilities are shaded.)

The process design for the blowdown water treatment plant was aimed at reduction of the suspended solids, total iron, and ammonia with the water quality standards as goals. It was recognized from the outset that filtration would be required in order to adequately reduce the suspended solids and iron concentrations. The dissolved iron in the stabilization lagoon system effluent is normally very low, and most of the iron is in an oxidized, suspended or colloidal state. In fact, approximately 40 percent of the suspended solids are iron, much of which is bound in the solids in the intake water from the Mississippi River. It was essential, therefore, that suspended solids in the treated blowdown be very low in order to maintain the total iron concentration at or below 1.0 mg/1.

The suspended solids levels in the lagoon effluent was found to be low enough to permit direct filtration, and clarifiers were not required. The decision was made, therefore, to provide direct filtration with standby equipment for the addition of polyelectrolyte filter aid to assist suspended solids removal by the filters.

For ammonia removal, the available treatment processes include biological nitrification/denitrification, air or steam stripping, ion exchange, and breakpoint chlorination.

After study of the alternatives, breakpoint chlorination was determined to be the most dependable year-round system for ammonia control. In this process ammonia is converted to nitrogen gas, a natural and harmless constituent of the atmosphere. When ammonia levels are low, breakpoint chlorination need not be used thereby saving chemicals and reducing costs. It would also tend to remove trace amounts of free cyanide, phenols, and sulfides in the blowdown water. The effect of breakpoint chlorination on the removal of iron and emulsified oil could not be quantitatively predicated, but it was believed that any effect would be beneficial.

For dechlorinating the treated blowdown prior to discharge to the Lake both activated carbon and sulfur dioxide injection were considered. It was decided to use sulfur dioxide for dechlorination due to system flexibility, and lower capital and operating costs. The feeding and metering equipment for sulfur dioxide would be identical to that used for chlorine. Close control of the treatment system would be required, however, to limit effluent ammonia levels generated by the action of sulfur dioxide on combined chlorine residuals.

A three-step system was developed, as shown in Figure 2. The first step is breakpoint chlorination with sodium hydroxide added to maintain the pH at or near 7.0. The second step is granular media filtration with standby capability to add polyelectrolyte filter aid. The third step is dechlorination with sulfur dioxide. The selected sequence provides for control of biological slimes on the filter sand.

The breakpoint chlorine dosage is based on influent flow and ammonia concentration levels, providing between 8 to 10 parts of chlorine per part of ammonia. The chlorine feed rate is trimmed by a signal indicating the free chlorine residual at the end of the contact period. The sulfur dioxide dosage is controlled to maintain an effluent chlorine residual concentration of less than 0.05 mg/1. The treated water flows from the water treatment plant to Horseshoe Lake in a 1500-foot long open channel to assure adequate dissolved oxygen levels. Because

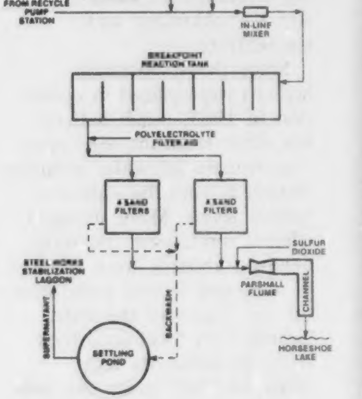
SODIUM HYDROXIDE
CHLORINE
FROM RECYCLE PUMP STATION
IN-LINE MIXER
BREAKPOINT REACTION TANK
POLYELECTROLYTE FILTER AID
4 SAND FILTERS
4 SAND FILTERS
SULFUR DIOXIDE
STEEL WORKS STABILIZATION LAGOON
PARSHALL FLUME
CHANNEL
SUPERNATANT
BACKWASH
SETTLING POND
HORSESHOE LAKE

Figure 2

Process Diagram of Blowdown Treatment Plant.

the rate of flow through the blowdown treatment plant is constant, and changes in the quality of the influent occur gradually due to the long detention times in the stabilization lagoon system, the plant can normally be operated automatically.

Granite City Steel completed its submissions to state and federal agencies, and approval for this treatment concept was received in the fall of 1975. Design was started immediately.

New Facilities

As shown in Figure 1, the new facilities include a recycle pump station, new pipelines, the blowdown treatment plant, and an outfall channel.

Recycle Pump Station

Effluent from the stabilization lagoon system is diverted to a new recycle pump station. Baffles and screens prevent logs, leaves, and other debris from entering the wet well feeding the pumps. Four vertical, mixed-flow, 450-hp pumps were rated at between 23 and 31 mgd, depending upon head conditions. Normal operation of the pump stations is to have two pumps running with 25 mgd going to the blowdown treatment plant and 37 mgd going to the mill reservoir.

Pipelines

Three major transmission pipelines were constructed in the recycle and treatment system.

48-inch Recycle Line—The 48-inch recycle line consists of approximately 9000 feet of prestressed concrete cylinder pipe with rubber and steel joints. The joints received interior and exterior mortar grouting for corrosion protection. The entire pipeline is electrically bonded, and cathodic protection inspection stations were installed at four locations where the pipeline crosses utility lines. Eight air relief valves were installed at the high points of the pipeline to prevent air binding. The pipeline design includes slow-closing check valves on the pump discharge and a pressure relief/surge tank system to eliminate water hammer problems.

30-inch Treatment Plant Supply Line—The 30-inch-diameter line supplying the treatment plant is approximately 750 feet long and is of the same material and construction as the 48-inch recycle line. This pipeline is also electrically bonded for cathodic protection.

36-inch Gravity Line—A 36-inch gravity line runs from the treatment plant to the steelworks stabilization lagoon. This provides an outlet for the treatment plant effluent during startup operations and can serve in the future as an emergency outlet during upset periods.

Blowdown Treatment Plant

The treatment sequence in the blowdown plant includes breakpoint chlorination, filtration, sulfonation, and the associated instrumentation.

Breakpoint Chlorination—Control of pH during the breakpoint chlorination reaction is achieved by addition of 50 percent sodium hydroxide prior to addition of the chlorine to a side stream of the influent water. The control system maintains the pH at or near 7.0. The caustic soda is stored indoors in a 15,000-gallon tank and metering pumps provide a peak feed rate of 1,320 gallons per day. The chlorination system uses gaseous chlorine with storage in 55-ton railroad cars on separate spurs constructed as part of the project. There is also provision for storage of one-ton chlorine cylinders as an emergency supply. The three chlorine evaporators are each rated at 8,000 pounds per day, and three chlorine feeders each have capacities ranging from 400 to 8,000 pounds per day. The detention time in the breakpoint chlorination reaction tank is 5 minutes.

Filtration—The filters are gravity units with 36 inches of sand as the filter media. There are two units with four cells in each unit. Each cell measures 20 ft x 27 ft x 20 ft in depth. The total available filter surface area is 39,000 square feet, and the filtration design rate for seven cells in operation is 5 gpm/sq ft. The backwash flow rate can be varied from 15 to 20 gpm/sq ft with an air scour providing 3,500 cfm at 5 to 7 psig. Control of the filters may be manual or automatic with the influent flow distributed to the other cell when one cell is being backwashed. The polyelectrolyte filter aid system can function with either powder or liquid forms at an average dosage rate of 21 pounds per day, and a maximum rate of 420 pounds per day. Filter aid, when used, is added to the water just prior to filtration.

Sulfonation—The liquid sulfur dioxide is stored in one-ton cylinders with space provided for 16 cylinders. Two evaporators are each rated at 4,500 pounds per day, and two sulfonators are each rated at from 70 to 1,425 pounds per day. The sulfur dioxide feed rate is designed for a 1:1 ratio with the chlorine residual in the filter clear well.

Instrumentation—The instrumentation system includes flow meters in the treatment plant influent and effluent lines, and an influent ammonia meter. Amperometric chlorine residual meters record the free chlorine residual at the outlet of the breakpoint reaction tank and the combined chlorine residuals in the clear well and in the final effluent. There is also a pH meter at the head end of the breakpoint reaction tank and a turbidity analyzer for the final effluent. Samples of raw wastewater breakpoint reaction tank effluent, clear will contents, and final effluent are pumped continuously to a sink in the treatment plant laboratory.

Results and Conclusions

Although the blowdown treatment plant involves a relatively sophisticated chemical process, the operators have been able to learn how to manage it quickly and successfully. The construction was completed on schedule so that there was a two-month period available to bring the system on line before the deadline specified in the NPDES* permit. The operating period has been too short to gather extensive effluent data for this paper, but the results to date have been excellent with all parameters below the permit requirements.

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* NPDES refers to the National Pollutant Discharge Elimination System provided for in the Water Pollution Control Act Amendments of 1972 adopted by the U.S. Congress.

Recycle of treated wastewater permitted Granite City Steel to achieve significant savings in both capital and operating costs while meeting the State of Illinois water pollution control regulations, both immediate and for the foreseeable future.

Another advantage of the recycling approach is that it permits Granite City Steel to continue to supply Horseshoe Lake with water of high quality to support a year-round recreational base in a State park and thus prevent the threat of the Lake becoming dry due to inadequate water supply.

Secondary benefits of the program include retention and continued use of the existing treatment systems. Recycling from the stabilization basins provides the mill with a water source containing lower solids content than that withdrawn from the Mississippi River.

In conclusion, Granite City Steel Division of National Steel Corporation is committed to environmental quality and water pollution control. The new treatment system has no by-pass. In other words, all water discharged to Horseshoe Lake must pass through the blowdown treatment plant. The new facilities involved a large capital investment and will have substantial operating and maintenance costs; however, these costs are considerably lower than they would have been without recycling. ☐

Reference

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Utilization of Sea Water in a System of Recycling Water Supply of Industrial Enterprises

By S.P. Sukach, Yu.D. Klovatskly, I.B. Shenderovich, Kharkov Devision of VNIIVODGEO

The problem of supply of service water for industrial enterprises located in coastal areas where there is a shortage of fresh water may be resolved either through transportation of water for a considerable distance from fresh water sources or by desalting sea water and lastly through utilization of sea water for industrial water supply without desalination. The first of the three methods demands considerable material and financial expenditures. The second one at the present stage of elaboration of methods for sea water desalting is also economically unfeasible. Utilization of sea water without desalting for an industrial water supply not requiring water of special quality at present should be considered as the most feasible and economically acceptable.

The subject of the report includes questions concerning peculiarities of utilization of sea water, without desalination, in the systems of recycling water supply of industrial enterprises. The report is based on results of scientific research works, publications and patent data, as well as on the experience of operation in the Soviet Union of water supply systems using sea water.

Sea and ocean water is characterized by high degree of mineralization, constancy of pH value and salt content as well as by strictly determined relations of components, low carbonate hardness, which does not exceed 2.8-3.4 mg-equiv/1 and by considerable value of total hardness.

Major part of sea water salt content is represented by chlorides while carbonates make up only 0.4%. However, from the point of view of stable properties, when using sea water for supply of cooling systems carbonic acid equilibrium plays the same main role as in fresh waters where carbonates prevail. Of all low-soluble components present in sea water calcium carbonate is that component which may, when crystallizing, form deposits on heat exchanger walls, i.e. scale deposits. This sharply reduces heat conduction of heat exchanges and increases hydraulic resistance of pipelines.

Presence in sea water of comparatively high amount of highly soluble salts, the total concentration of which in different seas and oceans may be within a range of 7-35%, with predomination of chlorides, facilitates increase of hardness salts solubility as compared to their solubility in fresh water. On the other hand, high degree of sea water mineralization leads to intensification of metals corrosion processes.

In order to determine optimal conditions of sea water utilization for recycling water supply of various industrial installations, the Kharkov Division of the VNIIVODGEO institute has carried out researches on pilot installations located on the Black and Azov seacoasts. Main attention has been paid to study of the changes in composition and properties of the water during its utilization in recirculating cooling systems. The experiments have been performed under operational conditions analogous to the industrial ones. Heating temperature was equal to 40 + 60°C, evaporation factor—1.5-3.0, velocity of water flow in pipes of the heat-exchanger—1.5-2.5 m/sec, Reynolds number (Re) was in the range of 30-75.10^3, Nusselt number (Nu)—180-280, heat load was equal to 40-60.10^3 kilo cal/m^2.hr.

Investigations have demonstrated that the change of nearly all components of salt content of recycled sea water depends upon the evaporation factor and was similar in all studied regimes. The only exceptions are alkalinity and concentration of dissolved gases.

It is shown by the experiments that the increase of evaporation under the same temperature causes the growth of alkalinity, but with the increase of water heating temperature, at the same degree of evaporation, alkalinity decreases. Increase of total alkalinity not in accordance with evaporation degree but to a somewhat lower value takes place due to partial decay of bicarbonates and their transformation into carbonates on one hand and heterogenous process of equilibrium between solid and dissolved phases of carbonate calcium on the other. Preservation of constant limiting value is a result of the dynamic equilibrium between bicarbonates decay and introduction of their new portions with make-up water for the system.

Evaluation of recycled sea water stability according to Langellie, experimental determination of its stable properties according to GOST—3313-46 as well as calculations of the degree of its supersaturation by calcium carbonate showed that under all operation regimes it was supersaturated by calcium carbonate and was inclined to produce carbonate deposits. Supersaturation grows with the increase of temperature and degree of evaporation.

In addition to chemical analysis, during experimental researches on pilot installations in accordance with methodology of statistical planning of experiment observations were carried out as well as monitoring of the processes of low-temperature scale formation and metals corrosion under conditions of recycled and direct-flow water supply.

Processing of obtained data made it possible to design mathematical models of processes of scale formation and metals corrosion rate depending on parameters of water supply systems operation. These dependencies were approximated by corresponding curves enabling in a simple way to make a selection of optimal modes of water supply systems operation with utilization of sea water.

Generalizing results of performed researches makes it possible to conclude that when the heating temperature is up to 45°C and the evaporation degree is equal to 1.5-3.0 sea water is sufficiently stable and may be used in cooling systems of recycled water supply without any stabilizing treatments.

Stability of supersaturated solutions of carbonic acid compounds under these conditions may be attributed to combined action of several factors: decrease of bicarbonate and carbonic ions activity due to increase of ion force of water solutions, depending on degree of water mineralization, availability of complexes or ion pairs causing decrease in concentration of scale-depositors free ions as well as influence of micropurities which, being adsorbed on the surface of microcrystals, are inhibiting their growth.

When sea water is utilized in the systems of recycling water supply operating at higher temperatures of water heating or under higher heat loads of heat exchangers, its stability is lost. To ensure scale-free conditions of operation it is necessary to carry out stabilizing treatment of make-up water by the same methods which are recommended for this purpose in fresh water systems, for example by acidification, recarbonation, magnetic treatment.

Corrosion tests included determination of corrosive activity of sea water in the systems of recycled and direct-flow water supply in respect to metals (steel, cast iron, copper, brass), depending on temperature of heating, water flow velocity, degree of evaporation and duration of metals submersion into sea water. Investigations demonstrated that direct-flow water at the temperature up to 45°C has higher corrosive effect (approximately 2 times higher) on all tested metals than the corrosive effect produced by water of recycling water supply systems. Reduced corrosive activity of recycled water may be explained by combined action of several factors, dominant of which are the following ones:

- lower concentration of dissolved oxygen due to higher mineralization and temperature of recycled water.
- presence of a very thin layer of carbonate film on the surface of metal contacting with water.

Increases of water heating temperature up to 60°C causes more intensive growth of corrosive activity of direct-flow water. On test samples, fixed in heat exchangers of recycled water supply systems, at the same temperatures appear some scale deposits.

In addition to the above considered investigations, some experiments for determination of conditions of sea water utilization in the systems of recycling water supply of gas purifiers of blast furnaces have been performed. As a result of the study of stability and corrosive activity indices of recycled water and comparison of these indices with ones for direct-flow water it was found that at heating temperatures up to 55°C and evaporation factors up to 3.0, the sea water is sufficiently stable and may be utilized in the systems of recycling water supply of gas purifier without special stabilizing treatment.

Corrosion tests showed that the speed of steel and cast iron corrosion in the water of the system of recycling water supply is 7-8 times lower than in direct flow water. All this, alongside with prevention of pollution of sea water areas adjacent to plants, enables preference to be given to recycling systems as compared to direct-flow ones.

Alongside with the investigations carried out on natural sea waters, mineralization of which did not exceed 18%, special experiments were performed in order to determine conditions of use of highly mineralized sea water in recycling water supply systems. They were performed on pilot installations incorporating all elements of operating systems of water supply typical for TPS using water similar in its composition to water of the Aden Gulf of the Red Sea.

Such water has been prepared by dissolving in drinking water natural sea salts up to the concentration equal to 45%.

Experiments made it possible to draw a conclusion about the possibility of using this water in recycling systems with a heating temperature up to 50°C, degree of evaporation up to 1.5, velocity of water flow in heat exchangers pipes equal to 1.5-2.0 m/sec with stabilizing treatment of the water for scale deposition prevention being unnecessary. Corrosive activity of the recycled water, due to availability of thin, hardly perceptible film, is approximately 2-3 times lower in comparison to corrosive activity of direct-flow water. However, it does not eliminate the necessity of anticorrosive protection of metals.

At present, a large number of corrosion control methods are known, among which the dominant place belongs to the following ones: use of corrosion-resistant materials, application of special protective coatings, arrangement of cathodic and anodic protection, treatment of water by inhibitors. Under conditions of enterprises of power-producing, metallurgical, chemical, machine-building branches of industry, where the water consumption reaches the highest amounts, the first three methods should be considered as the most acceptable ones. It is also necessary to take into account the possibility of utilization of such methods as replacement of direct-flow water supply by recycling one and temporary increase of circulating water heating temperature for formation of protective carbonate film on metal surfaces contacting with water.

Advantage of recycling water supply over a direct-flow one is also confirmed by such an important fact as insignificant or complete absence of biological growths. Control of this phenomenon when large amounts of water are consumed is of considerable difficulty during certain seasons of the year. In the systems of recycling water supply as a rule only those sections are subject to biological growth, which are connected with supply of additional "fresh" water from sea. However, this does not cause especially appreciable complications since usage of make-up water does not exceed 3-5% of total water consumption.

For control of biological growths in supplying pipelines bringing make-up water to recycled water supply systems it is better to use reagentfree methods. Among them it is possible to recommend back washing by used water heated up to 45°C at least once per two weeks with a duration of 4-5 hours. Such washing should be done when there is a stand-by pipeline and short length pipelines for make-up water delivery which are laid down with reverse gradient. This control can also be performed by emptying pipelines every 15 days for the period of 7-8 days.

In low-capacity systems it is possible to use reagent methods, for example, chlorination of make-up water in such a way as to provide concentration of residual chlorine equal to at least 0.25-0.50 mg/l.

One of the sufficiently effective methods for reduction of biological growths intensity is also filtering of fresh sea water. For these purposes one may use water intake facilities of filtration type, revolving nets made of capron fibre, nickel or steel non-corrodible threads.

Expedience of sea water utilization in the systems of water supply of industrial enterprises of the southern areas of the USSR, located on the Black and Azov seacoasts is proved by performed technical and economical calculations.

So, at certain conditions sea water may be successfully utilized in the systems of recycling water suppy without its desalination or other complicated special pretreatment. It enables prevention of pollution of sea water areas by wastewaters.

Use of sea water for industrial water supply makes it possible to economize fresh water which is in short supply in many seaside areas and as a result of it to receive appreciable technical and economic benefits.

Municipal and Industrial Wastewater Treatment and Reuse

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and Dennis S. Lachtman
Environmental and Occupational Health Analyst
Envirotech Corporation
Menlo Park, California

Introduction

The opportunity to participate as a member of the USA-USSR Working Group for the fifth Symposium appearance with this prestigious group of American and Soviet scientists is an honor for which I am deeply appreciative. As suggested by the title, this paper will highlight several types of current water reuse systems.

In my own California community where there is a drought, water reuse is a question of vital importance. Since the growth of population and industry in countries like the United States and the Soviet Union requires ever increasing amounts of water, availability of water is critical. In the U.S. we are faced with the problem of providing sufficient amounts of an acceptable quality water in addition to maintaining the best environmental quality.

Water reclamation, although previously not terribly popular, widely used or understood, is a means to alleviate this problem. As the subject of this discussion is principally wastewater, wastewater treatment, wastewater reuse and repurified wastewater as a potential untapped resource, let's think about wastewater that's presently in our tap water resources. Frequently, the mention of reusing wastewater brings a certain emotional barrier to our minds, and so I'd like to just go through some examples to show that this isn't as off base as many have normally believed.

In Nassau County, New York, septic tanks are used as the principal means of treatment, and this water, the overflow water, actually reenters the underground water supply which then enters the drinking water supply system. Nitro, West Virginia, draws its wastewater from the Kenawha River and this is a well known source of industrial and municipal waste.

A U.S. Government survey of 155 cities over 25,000 in population using surface water showed that 145 of them have sewage constituents in their water sources that may consist of up to as much as 17 to 18½ percent by volume in the dry season. The Denver area, which was visited by a Soviet delegation in 1974, happens to be one of those communities having these higher sewage volume levels in their water supply.

Cleveland gets its drinking water from Lake Erie, which is known to contain industrial and municipal sewage. London gets 19 percent of its metropolitan drinking water supply from the River Lee, 10 miles downstream from the Rye Meads Treatment Plant, the highest quality wastewater treatment plant in the U.K.

Paris draws its tap water from the River Seine, but France is a bottled water society. As I was told on a U.S. environmental trade mission to Paris, no self-respecting Frenchman would drink tap water!

In summary, a recent U.S. Public Health survey showed 25% of some 3,500 samples from communities indicate tap water of a lower quality than the high quality effluent from some of the treatment plants that I'll be discussing. Projected nationally, this was equal to about 50 million people in the U.S. drinking tap water of a quality lower than that which is received from an advanced waste treatment plant.

Accordingly, water reuse is not a novel or new concept, but merely one that has not been popularly recognized and has been overlooked in long range planning.

Water Reuse

In the United States, there are approximately 360 projects operating to reclaim municipal wastewater.[3] Eighty percent of these projects are located in California and Texas.[3] Present municipal reuse volume in the U.S. is 5 x $10^8 m^3$/yr (136 billion gallons per year), which is less than 2% of the total municipal waste volume.[2]

Of this municipal reuse volume, 40% or 2 x $10^8 m^3$ (54 billion gallons) is utilized by industry and 57% was used for agricultural purposes. The majority of industrial uses are included within the categories of cooling and boiler feed water, although, as mentioned previously, unintentional water reuse occurs widely in various river and lake basins. Figure 1 illustrates some of the variety of purposes that treated watewater can serve.

Separate from municipal wastewater treatment systems, industrial process water reuse occurs primarily in the form of water regeneration or recycling. Examples of municipal and industrial recycling systems will be discussed below.

Municipal Water Reuse Systems

In areas undergoing drought circumstances, such as California, water reuse can no longer be neglected. In California, the supply of water is expected to fall short of demand by 2 to 4 million acre feet (2.5 to 5 x 10^9 m^3) in 1990 and a shortage of 3 to 10 million acre feet (3.7 to 12.3 x 10^9 m^3) by 2020.[5] 2.2 million acre feet (2.7 billion m^3) of groundwater is depleted from groundwater basins every year in California.[5] These predictions in conjunction with such variables as below normal rainfall should lead to the recognition for the need to develop increased water resources. While conservation can help alleviate supply deficits, industrial and population growth can be stifled when water resources are in short supply. Water reuse, where appropriate, can offer to reduce water shortages.

Some examples of advanced municipal treatment systems that purify water for reuse are shown in Figure 2. Since a more detailed discussion than will follow of such advanced treatment processes is beyond the scope of this paper, I have appended to this paper more detailed information on this subject for those who are so inclined.

The flowsheet in Figure 3 is the Windhoek, Namibia, wastewater treatment plant which is the only advanced waste treatment installation in the world that directly integrated purified wastewater into the city's domestic water supply on a continental basis. The facility played a vital role in alleviating the water shortages during the 1969-1971 acute drought. This installation, consisted of a conventional wastewater treatment plant which had algae lagoon and physical-chemical treatment stages added. The effluent met the United Nations World Health Organization (WHO) standards and was used to supplement up to 50% of the tap water for this community of approximately 70,000 people.[1] [4]

A more modern reclamation plant in Pretoria, (Daspoort) South Africa reclaims 4927 m^3/day (1.3 x 10^6 gallons) of effluent that also meets WHO drinking water standards. The flowsheet for this physical chemical treatment plant is shown in Figure 4. In 1976, the Windhoek plant was further modernized to enable it to achieve operating efficiency levels similar to those being achieved in Pretoria.

At South Lake Tahoe, physical-chemical treatment was added to conventional or secondary treatment and that water also meets the United Nations WHO standards. This water has been used to form Indian Creek Reservoir, a trout lake, for swimming and for grazing areas. This biological plus physical-chemical advanced wastewater treatment flowsheet is shown in Figure 5.

Colorado Springs is one of the most recent advanced waste treatment plants in the U.S., again a conventional plant to which physical-chemical treatment was added. (see Figure 6). The levels of oxygen-demanding substances and suspended solids are low enough that tertiary quality water, some two million gallons a day capacity from this treatment plant, could be sold to the next door public utility for industrial cooling water make-up.

The Rye Meads Treatment Plant in the U.K. which I mentioned earlier, has an extended conventional biological treatment plant. It has two standards: 10 parts per million of oxygen-demanding substances and suspended solids in the wet season, and only half that amount in the dry season, and it, as I mentioned, flows into the River Lee that supplies about 19 percent of London's tap water. Figure 7 is an aerial view of this treatment plant which shows the processes all the way from the sand filtration through the solids handling units.

Another water reclamation plant that is about to start operating is the 113,500 m^3/day (30 million gallon/day) Central Contra Costa Sanitation District (CCCSD) Water Reclamation Plant in Concord, California. This plant flowsheet, as shown in Figure 8, is designed for a possible expansion to handle up to 455,000 m^3/day (120 million gallons/day).[6] The influent characteristics are expected to average 220 mg/1 BOD, 240 mg/1 suspended solids, 30 mg/1 nitrogen N, 11 mg/1 total phosphorus as P. After treatment, the effluent values will be 3.5 mg/1, 6.0 mg/1, 2.0 mg/1 and 0.5 mg/1, respectively.[6] The effluent will be used by the following five industries: Phillips Petroleum, Shell Oil, Stauffer Chemical, Monsanto and the Pacific Gas and Electric power station. Reclaimed water in excess of industrial needs will be discharged into receiving Bay waters. Fortunately, these discharge waters will have little if any deleterious effect on receiving waters as the effluent would be virtually free of oxygen demanding materials, nutrients and toxicants. So far, a minimum of 72,000 m^3/day (19 million gallons/day) have been purchased by the five named industrial concerns. Approximately 25% of the reclaimed water will be used for process purposes with the remainder allocated for cooling.

Included in the general area of water reuse are systems that add water of high treatment quality for recharge into underground waters. Numerous examples exist of such systems that are designed to augment subterranean water supplies and stop salt water intrusion into underground fresh water supplies. However, discussion of such systems is beyond the scope of this presentation.

Industrial Water Reuse Systems

Industrial facilities demand large quantities of process waters to supply their manufacturing processes. According to a 1968 study of the Great Lakes Basin the U.S. Department of Commerce, based on an Office of Business Economic Growth prediction plus an assumption of achievement in water conservation by industry, water depletion in the Great Lakes Basin could become a serious constraint to industrial expansion. By the year 2000 the vast Great Lakes Basin, including metropolitan Chicago, could be evaporating more water through its industries than the metropolis now withdraws from Lake Michigan for all its uses.[4]

As a result of heavy industrial demands, recycling or reclamation of wastewaters should become a critical factor in population and industrial growth. Methods that serve to reduce the ever increasing demand for water supplies will become necessary to allow industrial growth.

An industry that traditionally requires vast supplies of water has been bleached kraft pulp milling. A new innovation, the closed-cycle mill with salt recovery (SRP) promises both to reduce water consumption and to alleviate the problems of environmental degradation that have previously been associated with bleached kraft pulp mills. The closed-cycle-mill was first developed by W.H. Rapson and D.W. Reeve in their research efforts at the University of Toronto[18]. Erco-Envirotech, a joint venture of American and Canadian business interests, continued the development of the closed-cycle concept for commercial applications, as was reported at last year's joint symposium in Moscow.[13]

The closed-cycle mill combines a number of innovative procedures providing a process design that eliminates discharges through internal recycling and reduces water consumption by 83%. The system also recovers fibers, chemicals, organics and heat normally lost to external treatment systems in conventional kraft mills.

Located in the heavily industrialized Great Lakes area, this closed cycle mill with SRP has begun operations this year and produces 250,000 tons (227,273 metric tons) per year of bleached market grade pulp. Many of the process techniques for this plant have either been demonstrated or are being used in mills throughout the world today. Those process techniques already used elsewhere and contained in the Thunder Bay flowsheet are the following[8]:

1. Countercurrent washing in the bleachery;
2. chlorine dioxide substitution for chlorine in the first bleaching stage;
3. steam stripping of contaminated condensate; and
4. a closed screen room and spill tanks to accommodate temporary process upsets and allow subsequent recycle.

The unique aspect of the Thunder Bay flowsheet is the total recycle of bleachery effluent, as shown in Figure 9, to the unbleached portion of the mill. Normally, the problem with such a recycle procedure would be the build-up or introduction of sodium chloride, which must be removed at the same rate it is introduced. The Erco-Envirotech SRP System was developed to solve this problem.

Economics

It must be recognized that economic data vary greatly between different processes and their locations. However, some consideration as to the value of reclaimed water should be compared to the differential between secondary and tertiary treatment systems. In a previous symposium paper[10] evaluating the costs of tertiary treatment plants and independent physical chemical treatment plants, I found that the cost of tertiary quality water was approximately 60¢/1000 gallons (16¢/m^3) and that the difference between the cost of producing secondary and tertiary quality water ranges from 6 to 14¢/1000 gallons (1¢-3¢/m^3) for a 30 million gallon/day plant (133,550 m^3/day). Since the price of potable water is on the order of 40 to 80¢ per 1000 gallons (16 to 19¢/m^3), tertiary quality water when used as a substitute or alternative for fresh water supplies can yield substantial savings. In South Africa the estimated cost of tertiary treated water from a 50,000 m^3/day (13,000,000 gallons/day) treatment plant is approximately 15¢ per m^3 (57¢/1000 gallons), which is of a magnitude similar to the total cost of fresh water supplies in the U.S. However, these prices whether they occur in the U.S. or in other countries are most likely a very small fraction of the full price of fresh water when one considers the cost of reclaimed water to merely reflect the cost difference between secondary and tertiary treatment levels. Considering that reclaimed water for cooling purposes is valued between 26-40¢/1000 gallons (about 8¢/m^3), the 6¢ to 14¢/1000 gallons (1-3¢/^{3}) added cost of reclaimed water (tertiary water from secondary treatment) is of positive economic benefit.

The economics of the closed-cycle mill with SRP are quite favorable. Figure 10 illustrates a theoretical model of a 900 short ton per day (TPD) (818,000 kg/day) coniferous bleached kraft pulp plant similar to the Thunder Bay flowsheet.[11] The data from Figure 10 show the estimated annual savings in operating costs for the closed-cycle mill in comparison to conventional bleached kraft pulp mills are in excess of $5,000,000 (3,785,000 rubles) or approximately one-half the capital costs. These savings mean that the capital costs would be recovered in about two years. Additionally, these statistics exclude such factors as the value of the salt (NaCl) recovered or the potential value of heat that could be recovered from the clean cooling water makeup.[13]

Health Implications

In the U.S. wastewater treatment performance data are not available for every parameter included in existing drinking water contents.[1] Current data indicate that where information is available the types of processes previously discussed can conform to all standards being measured.

The present tertiary quality treatment systems deliver wastewater effluents that are equal to or surpass the quality of many suitable water supplies. However, such treated effluents often have small residuals, as that extensive testing has shown that viruses do not appear to have been a problem.[5] During 1976, studies at Daspoort also confirmed the Windhoek sampling data, showing that viruses and bacteriological contaminants were present in treatment plant influent, but absent from the treated effluent.

Epidemiologic studies looking at the long-term health consequences of trace organics and other trace residuals in tertiary treated wastewater of the Windhoek municipal population were unable to detect any change in disease or morbidity patterns that could be associated with the consumption of tertiary wastewater. While more epidemiologic data in the U.S. and other countries are needed to provide better assurances of safety, the South

African work is an initial positive data point indicating a probable lack of adverse chronic health effects associated with consumption of high quality reclaimed wastewater.

do fresh potable water sources, of organic carbon and chlorinated organics. How important or critical from a health standpoint are these substances? We do not presently know the answer to this question, but some research on this subject is underway in this Country.

Yet, we can look to Windhoek for further information on the health implication of drinking reclaimed water. It turns out

Summary

We have discussed the need and importance for maintaining adequate water supplies. The use of reclaimed water, where appropriate, is clearly a means of alleviating water shortages and insuring adequate water supplies.

Tahoe, Windhoek, Daspoort, Colorado Springs, Rye Meads, and Thunder Bay are all examples of existing technology to purify virtually any wastewater to a high quality reclaimed water at a reasonable cost, and possibly a saving, when compared to alternate sources and the damage done to the environment by the discharging of less purified effluents. Additionally, processes such as the one at Thunder Bay, Ontario, actually return enough savings to be considered profitable after only two years.

While health data are sparse, the presently available studies have shown no adverse long-term or other health problems associated with drinking or using high quality effluents as such efforts have been reported in the U.S. and South Africa. □

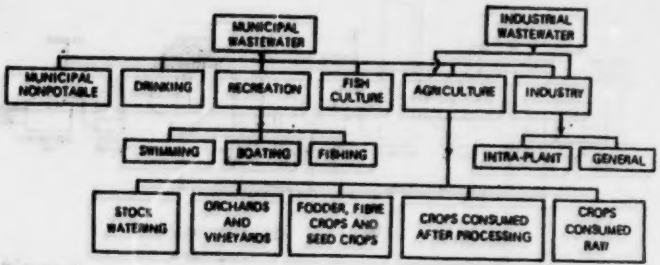
MUNICIPAL WASTEWATER
INDUSTRIAL WASTEWATER
MUNICIPAL NONPOTABLE
DRINKING
RECREATION
FISH CULTURE
AGRICULTURE
INDUSTRY
SWIMMING
BOATING
FISHING
INTRA-PLANT
GENERAL
STOCK WATERING
ORCHARDS AND VINEYARDS
FODDER, FIBRE CROPS AND SEED CROPS
CROPS CONSUMED AFTER PROCESSING
CROPS CONSUMED RAW

Figure 1

Intentional reuse of wastewaters. From the World Health Organization Technical Report No. 517, 1973 (3).

Location	Technology	Effluent Quality	Effluent Use
Windhock, South West Africa	Biological-algae-physical-chemical	WHO Standard	Tap Water
Lake Tahoe California	Biological-physical-chemical	WHO Standard	Trout lake, swimming irrigation
Colorado Spgs, Colorado	Biological-physical-chemical	BOD 11 ppm* SS 1.5 ppm	Industrial cooling water
Rye Meads, U.K.	Extended-biological	BOD 10-5 ppm SS 10-5 ppm	Up to 20% of London tap water
Central Contra Costa Sewage Treatment Plant	Lime plus Biological	BOD 2.0 pp, SS 1.0 ppm	Industrial Cooling and Processing

Figure 2

Examples of Advanced Wastewater Treatment Technology

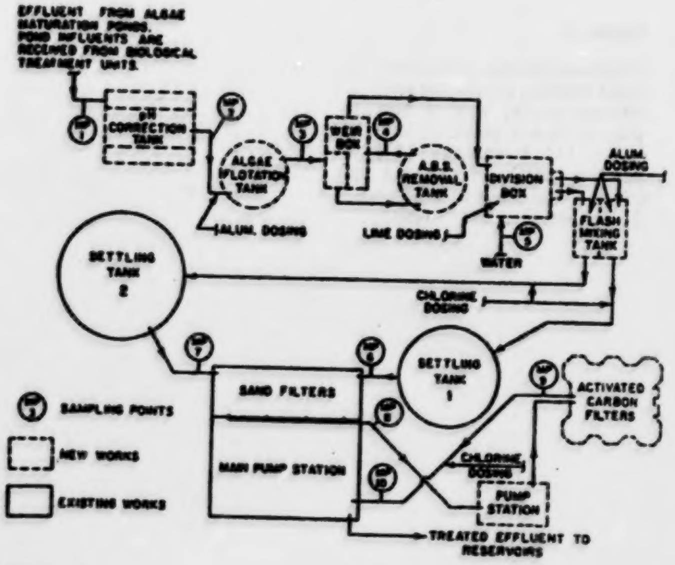
EFFLUENT FROM ALGAE MATURATION PONDS. POND INFLUENTS ARE RECEIVED FROM BIOLOGICAL TREATMENT UNITS.
pH CORRECTION TANK
ALGAE FLOTATION TANK
WEIR BOX
A.B.S. REMOVAL TANK
DIVISION BOX
ALUM. DOSING
FLASH MIXING TANK
ALUM. DOSING
LIME DOSING
WATER
SETTLING TANK 2
CHLORINE DOSING
SETTLING TANK 1
SAND FILTERS
MAIN PUMP STATION
ACTIVATED CARBON FILTERS
CHLORINE DOSING
PUMP STATION
TREATED EFFLUENT TO RESERVOIRS
1
2
3
4
5
6
7
8
9
10
SAMPLING POINTS
NEW WORKS
EXISTING WORKS

Figure 3

Water reclamation plant at Windhoek

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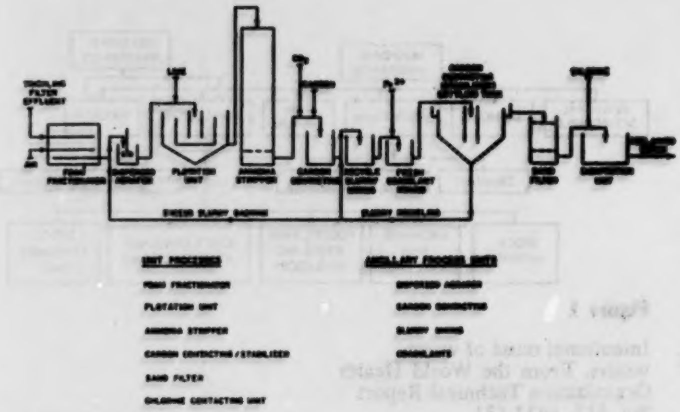
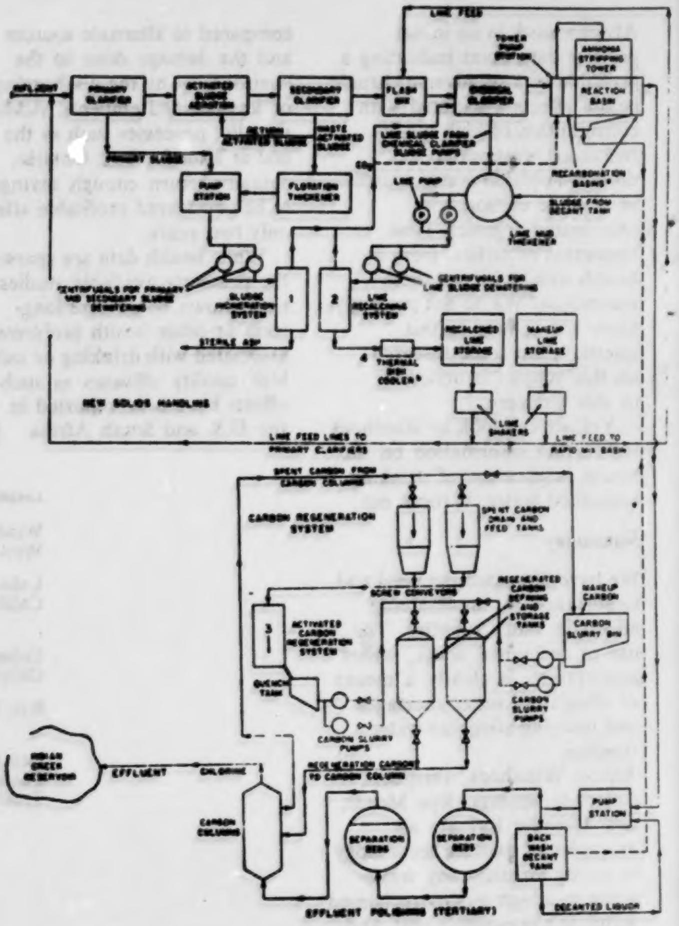

TRICKLING FILTER EFFLUENT
LIME
FOAM FRACTIONATOR
FLOTATION UNIT
AMMONIA STRIPPER
CARBON CONTACTING
SAND FILTER
CHLORINE CONTACTING UNIT
UNIT PROCESSES
FOAM FRACTIONATOR
FLOTATION UNIT
AMMONIA STRIPPER
CARBON CONTACTING / STABILIZER
SAND FILTER
CHLORINE CONTACTING UNIT
ANCILLARY PROCESS UNITS
DISPERSED AERATOR
CARBON CONTACTING
SLURRY DOSING
COAGULANTS

Figure 4

Flowsheet of water reclamation plant installed at Daspoort, South Africa.


LIME FEED
TOWER PUMP STATION
AMMONIA STRIPPING TOWER
REACTION BASIN
INFLUENT
PRIMARY CLARIFIER
ACTIVATED SLUDGE AERATION
SECONDARY CLARIFIER
FLASH MIX
CHEMICAL CLARIFIER
RETURN ACTIVATED SLUDGE
WASTE ACTIVATED SLUDGE
PRIMARY SLUDGE
LIME SLUDGE FROM CHEMICAL CLARIFIER SLUDGE PUMPS
CO_2
RECARBONATION BASINS
PUMP STATION
FLOTATION THICKENER
LIME PUMP
SLUDGE FROM DECANT TANK
LIME MUD THICKENER
CENTRIFUGALS FOR PRIMARY AND SECONDARY SLUDGE DEWATERING
SLUDGE INCINERATION SYSTEM
1
2
LIME RECALCINING SYSTEM
CENTRIFUGALS FOR LIME SLUDGE DEWATERING
STERILE ASH
4
THERMAL DISK COOLER
RECALCINED LIME STORAGE
MAKEUP LIME STORAGE
NEW SOLIDS HANDLING
LIME SHAKERS
LIME FEED LINES TO PRIMARY CLARIFIERS
LIME FEED TO RAPID MIX BASIN
SPENT CARBON FROM CARBON COLUMNS
CARBON REGENERATION SYSTEM
SPENT CARBON DRAIN AND FEED TANKS
SCREW CONVEYORS
REGENERATED CARBON DEFINING AND STORAGE TANKS
MAKEUP CARBON
CARBON SLURRY BIN
3
ACTIVATED CARBON REGENERATION SYSTEM
QUENCH TANK
CARBON SLURRY PUMPS
CARBON SLURRY PUMPS
INDIAN CREEK RESERVOIR
EFFLUENT
CHLORINE
REGENERATION CARBON TO CARBON COLUMN
CARBON COLUMNS
SEPARATION BEDS
SEPARATION BEDS
PUMP STATION
BACK WASH DECANT TANK
DECANTED LIQUOR
EFFLUENT POLISHING (TERTIARY)

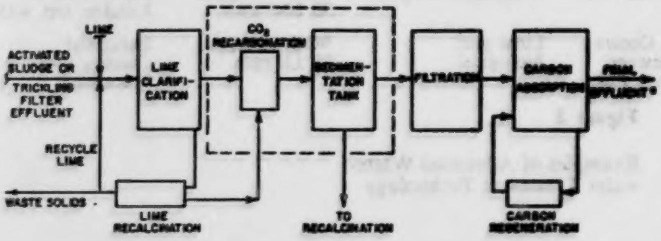

LIME
ACTIVATED SLUDGE OR
TRICKLING FILTER EFFLUENT
LIME CLARIFICATION
CO_2 RECARBONATION
SEDIMENTATION TANK
FILTRATION
CARBON ADSORPTION
FINAL EFFLUENT(a)
RECYCLE LIME
WASTE SOLIDS
LIME RECALCINATION
TO RECALCINATION
CARBON REGENERATION

Figure 6

Colorado Springs treatment plant section, producing an effluent quality that is acceptable as power plant makeup water. (a) It contains 11 mg. per liter BOD, 17 mg. per liter COD, 1.5 mg. per liter SS and 3 mg. per liter PO_4^{3-}. (16).

Figure 5

Public utility district water reclamation plant at South Lake Tahoe, California. (a) Carbon dioxide is added to water in reaction basin after it has passed through ammonia-stripping column. (b) Thermal disk is a processing unit with a heat-transfer medium. The solid, reclaimed lime is cooled by the disks as it passes between them.

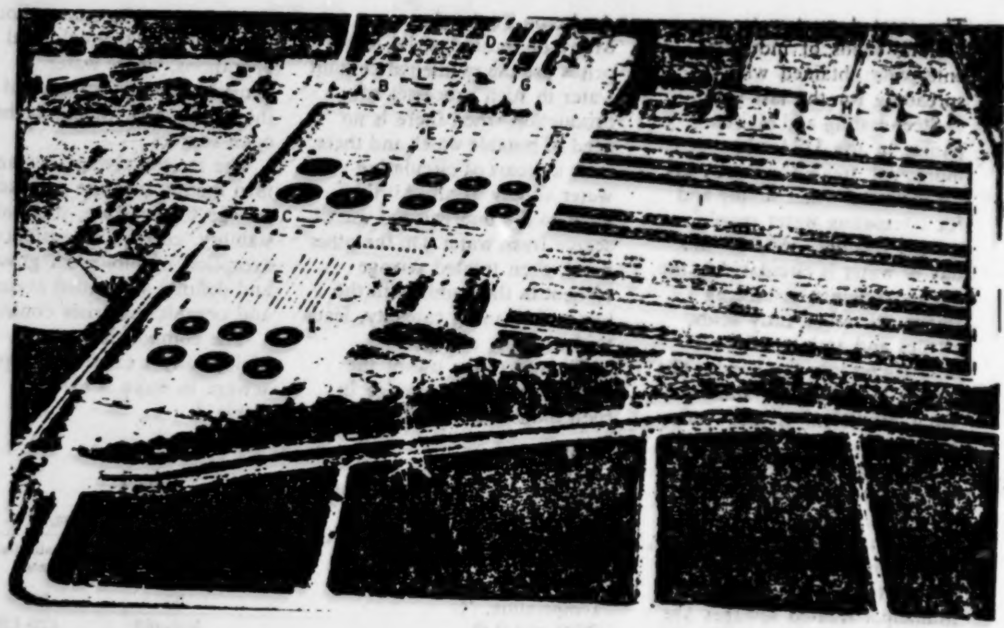


Figure 7

Aerial view of Rye Meads, sewage works at Rye Meads, England. Key: A. Compressor and return sludge house; B. Administration building and power house; C. Sand filtration plant; D. Sedimentation tanks; E. Aeration tanks; F. Final tanks; G. Primary digesters; H. Secondary digesters; I. Drying beds; J. Liquor settlement tanks; K. Sludge lagoons; L. Screens and grit channels.

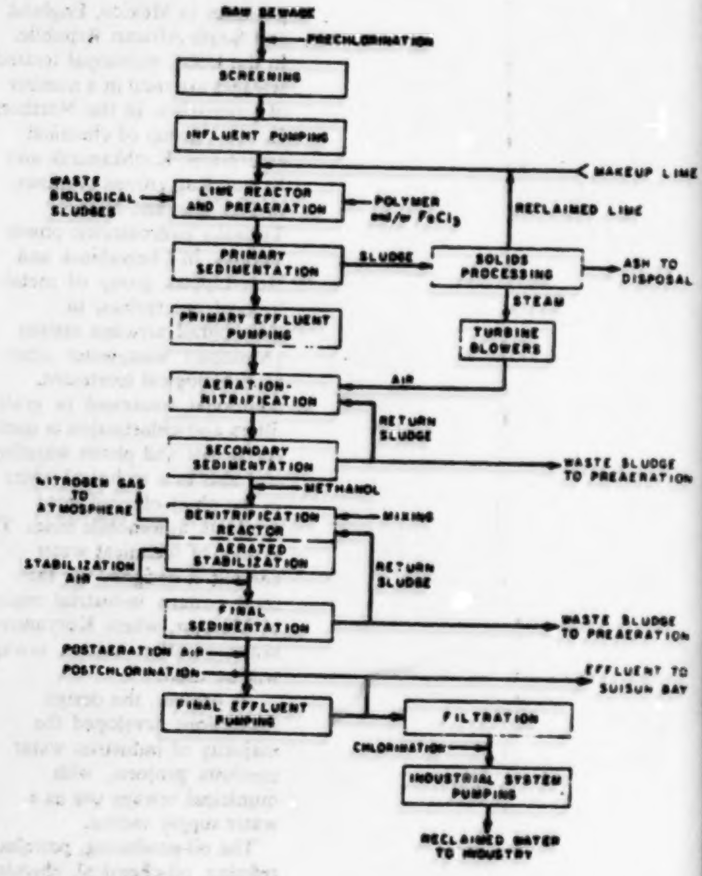

RAW SEWAGE
PRECHLORINATION
SCREENING
INFLUENT PUMPING
MAKEUP LIME
WASTE BIOLOGICAL SLUDGES
LIME REACTOR AND PREAERATION
POLYMER and/or $FeCl_3$
RECLAIMED LIME
PRIMARY SEDIMENTATION
SLUDGE
SOLIDS PROCESSING
ASH TO DISPOSAL
STEAM
TURBINE BLOWERS
PRIMARY EFFLUENT PUMPING
AIR
AERATION-NITRIFICATION
RETURN SLUDGE
SECONDARY SEDIMENTATION
WASTE SLUDGE TO PREAERATION
NITROGEN GAS TO ATMOSPHERE
METHANOL
DENITRIFICATION REACTOR
MIXING
AERATED STABILIZATION
STABILIZATION AIR
RETURN SLUDGE
FINAL SEDIMENTATION
WASTE SLUDGE TO PREAERATION
POSTAERATION AIR
POSTCHLORINATION
EFFLUENT TO SUISUN BAY
FINAL EFFLUENT PUMPING
FILTRATION
CHLORINATION
INDUSTRIAL SYSTEM PUMPING
RECLAIMED WATER TO INDUSTRY

Figure 8

Central Costa Costa Sewage Liquid Process Flow Sheet Treatment Plant, Concord, CA.

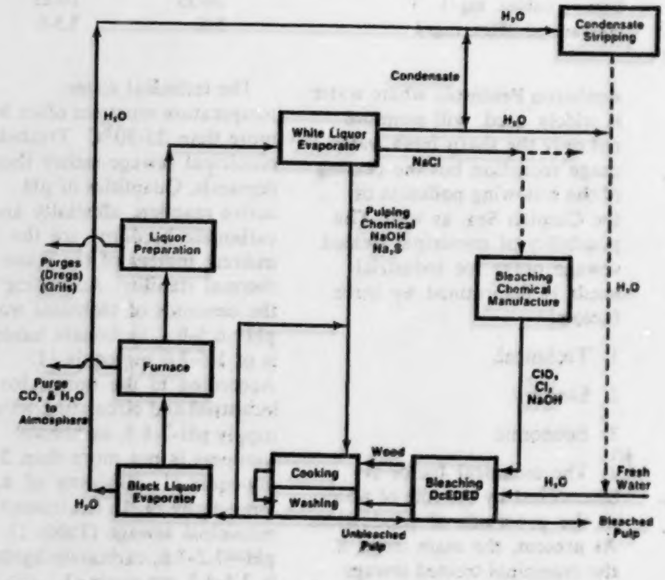

H_2O
Condensate Stripping
Condensate
H_2O
White Liquor Evaporator
H_2O
NaCl
Pulping Chemical NaOH Na_2S
Liquor Preparation
Purges (Dregs) (Grits)
Bleaching Chemical Manufacture
H_2O
Furnace
Purge CO_2 & H_2O to Atmosphere
ClO_2 Cl_2 NaOH
Wood
Cooking
Washing
Bleaching DcEDED
H_2O
Fresh Water
Black Liquor Evaporator
H_2O
Unbleached Pulp
Bleached Pulp

Figure 9

Closed-Cycle Mill

To the Question of Municipal Treated Sewage Use in Industrial Water Supply of the Apsheron Peninsula

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The treated wastewater use for the needs of industrial enterprise obtained wide spreading for the last yearr.

Steel-casting and oil companies of the USA use municipal treated wastewaters for technical water supply and for circulating water supply system feeding. 150.000 m^3/day of water is circulated in the chemical plants, producing spirits, glycerine, fatty acids, nitriles and amines, without discharging into the ponds. The industrial water-pipe stations, using municipal treated wastewaters, as a water source are built in Japan. Water, after coagulation and clarification processes, is supplied in a special mains of technical water, from which it's spread into 463 factories and plants. The municipal treated sewages are used for industrial water supply purposes in Mexico, England and South-African Republic. In the USSR municipal treated sewages are used in a number of enterprises: in the Northern-Donetsk group of chemical enterprises, Kachkanarsk and Krivoy Rog groups of mines, in Reftensk and Nizhni-Turinsky hydroelectric power stations, in Chelyabinsk and New-Lipetsk group of metallurgical enterprises; in Zelenograd aeration station (Moscow) wastewater after total biological treatment, additional treatment in grained filters and chlorization is used for streets and plants watering, and also as a technical water in the plant of reinforced products, automobile bases. The system of technical water conduit is designed for the south-eastern industrial region of Moscow, where Kuryanovskaya aeration station sewage will be used.

At present, the design institutions developed the majority of industrial water conduits projects, with municipal sewage use as a water supply source.

The oil-producing, petroleum-refining, oil-chemical, chemical, electro-technical, mechanical-engineering, wood-working, structural-materials production and other kinds of industries are the most widely used on the Apsheron Peninsula.

Many of the industrial enterprises use the municipal conduit water in such processes of production when there is no need of potable water and there is no systems of circulating water supply at all. All this leads to the unorganized use of scarce fresh water. On the other hand, even treated sewage effluent in the ponds with the low self-cleaning capacity, leads to the quality change.

Therefore, the use of the treated municipal sewage in such industrial branches of the Apsheron Peninsula where water is widely used, will promote not only the sharp fresh water usage reduction but the ceasing of the following pollution of the Caspian Sea, as well. The possibility of municipal treated sewage usage for industrial needs is determined by three factors:

1. Technical,
2. Sanitary,
3. Economic

1. The technical factor is determined by the role of water in the processes of production. At present, the main trend in the municipal treated sewage usage, mainly in the circulating water supply systems, is determined already rather clear. One can say the same about the number of technological operations, where water demands nearly correspond to the fresh water indices in the open sources.

The treated sewage demands turn mainly into the definite sewage temperature, thermal stability, corrosion resistance, exception of biological growth and definite suspended materials and organic materials content.

The composition of biologically treated municipal sewage in Baku is given in Table 1.

Table 1

Sanitary-chemical indices of the municipal sewage

Indices	Content, mg/1	
	untreated water	biologically treated water
Temperature, °C	30	30
COD, mg 0_2/1	300-480	120-150
BOD$_{total}$, mg/0_2/1	150-280	15-20.0
pH	6.6-7.1	7.2-7.6
Suspended materials, mg/1	90-150	20-30
Nitrogen: ammonium, mg/1	28-35	12-19
nitrates, mg/1	no	0.5-1.0
nitrates, mg/1	no	7.0-8.9
Phosphates, mg/1 P	2.1-3.3	1.0-1.8
Carbonate hardness, mg-equiv./1	2.5-4.5	3.5-4.5
Non-carbonate hardness, mg-equiv./1	3.0-5.7	3.0-5.7
Total alkalinity, mg-equiv,/1	4.0-5.5	4.0-5.5
Cl^1, mg/1	160-400	160-400
SO4^{11}, mg/1	350-500	350-500
Salt content (according to the tempered residue, mg/1)	1100-1500	1100-1500
Ether-solubles, mg/1	20-35	10-15
Hexsane-solubles, mg/1	5-8	3.5-6

The technical water temperature must not often be more than 25-30°C. Treated municipal sewage satisfy these demands. Quantities of pH active reaction, alkalinity and carbonate hardness are the indirect indices of the water thermal stability. According to the demands of technical water pH=6.5-8.4, carbonate hardness is of 1.5-2.0 mg-equiv./1. According to the norms for industrial and circulating water supply pH-7-8.5, carbonate hardness is not more than 5 mg-equiv./1, alkalinity of 4.5-5 mg-equiv./1. In the treated municipal sewage (Table 1) pH=7.2-7.6, carbonate hardness is 3.5-4.5 mg-equiv./1, alkalinity is 4-5.5 mg-equiv./1.

So, the indirect indices of the thermal stability satisfies the technical water demands. The water corroding characteristics were determined by the saturation index J, when $J = ph - pH_s = 7.4 - 7.34 = 0.06$, where pH_s is the quantity of the calcium carbonate balance saturation in the examined water, which is determined by the sewage temperature data, calcium concentration, alkalinity and total salt content. This saturation index quantity points to the fact that water is not aggressive and corroding. The intensive formation of biological growth may be prevented by the chlorization of the treated sewage with such doses of chlorine which allows to support the content of sedimentary chlorine not less than 1.5 mg/1, and use of such prophilactic measures as (hot water washing and mechanical dressing of pipes).

According to the technical water demands, the content of the suspended materials, BOD, COD, salt content makes up 10-20 mg/1 (which water movement velocity in heat-exchanging apparatus is 0.01-0.02 mg/sec), 75 mg 0_2/1, 10 mg 0_2/1 and 2000 mg/1. The content of the suspended materials in biologically treated municipal sewage (Table 1) is of 20-30 mg/1, COD—120-150 mg 0_2/1, BOD_{total} of 15-20 mg 0_2/1, the salt content of 1500 mg/1.

Therefore, biologically treated water in Baku should be additionally treated, according to the suspended materials indices, COD and BOD_{total}. Among all the presented methods of additional treatment of biologically treated sewage—sorption, coagulation, flotation, ozonization and so on, the filtration by means of grained loadings is the most simple and extended method, and it gives a great effect. Natural method of additional treatment in the biological ponds may be the most effective one in the south climatic conditions. That's why the experimental investigations on additional treatment of biologically treated municipal sewage in Baku were carried out in the biological ponds and on the rapid sandy filters, both in laboratory and semi-commercial structures.

Indices	Biologically treated municipal sewage	Biological pond with the natural addition	Rapid Sandy Filters without aeration	Rapid Sandy Filters with aeration
Temperature, °C	no > 30	no > 25	no > 25	no > 25
pH	7.2-7.5	7.5-8.5	7.5	7.5
COD, mg 0_2/1	120-150	50	60	55
BOD total	15-20	4.5	8	5.0
Suspended materials, mg/1	20-30	8-10	5-10	5.6
Ammonia Nitrogen, mg/1	12-19	5	15	15
Nitrites, mg/1	0.5-1.0	0.6	0.8	0.7
Nitrates, mg/1	7.0-8.0	1.5-3	4.0	5.0
Phosphates, mg/1P	1.0-1.8	0.6	1.0	1.0
Carbonate hardness, mg-equiv./1	3.5-4.5	4.5	4.5	4.5
Non-carbonate hardness, mg-equiv./1	3.5-5.7	5.8	5.8	5.8
Total alkalinity, mg-equiv./1	4.0-5.5	5.2	5.0	5.0
Chlorides, mg/1	160-400	160-400	160-400	160-400
Sulphates, mg/1	350-550	350-550	350-550	350-550
Salt content, mg/1	1100-1500	no 1500	no 1500	no 1500
Ether-solubles, mg/1	10-15	5	8	6
Dissolved Oxigen, mg/1	5-8	3	6	

Table 2

Sanitary-chemical composition of additionally treated sewages

The results of the experimental investigations on the additional treatment of the biologically treated effluent are given in Table 2.

As it is seen from Table 2 according to the technical water demands the residual pollution reduction in the additional treatment structures for suspended materials is of 5-10 mg/1, COD—of 50-60 mg/1, BOD_{total} 4.5-8 mg 0_2/1, ether-soluble materials is of 5-8 mg/1 on average, it allows to use the additionally treated municipal sewage in industrial enterprises water supply.

The carried out investigations allowed to define the main parameters of additional treatment structures. They are: residence time, depth, water-plants applying, the effect of organic pollutions reduction, etc.—for ponds; height, loading, the filtration velocity, the filtration cycle, filter washing and so on—for filters. All this is given in Table 3 where the comparison between quality and demands for different waters is given too.

From the sanitary point of view, additionally treated municipal sewage must be decontaminated, under the condition of the residual active chlorine content is not less than 1.5 mg/1, in this case the quantity of the intestinal bacilli group bacteria reduces to 99.1-100%.

Carrying out the special experiments on sanitary value of additionally treated sewage, the specialists from the Institute of Microbiology, Virusology and Hygiene after Musabekov of the Azerbaijan Health Department came to the conclusion about the possibility of additionally treated sewage usage for needs of industry in the Apsheron Peninsula. They recommended using additional treated sewage after the decontamination for needs of enterprises of different industrial branches in the Apsheron Peninsula, except for food industry, meat and milk industry, light and medical industry; in this case medical examination for the service staff is necessary, and it must be supplied with overalls. The water conduit must have a preventive specific coloration and tables, pointing that water is not potable.

At present, the repeated usage of treated sewage is considered to be as one of the most important national-economic measures. The economical factor of the additionally treated sewage repeated usage for industrial needs must be determined by stages. The discharge of the municipal conduit is the defining criterium on the first stage. However, considering the possibility of the repeated usage of the all volume of municipal sewage in Baku, an economic factor is estimated by the reduction of damage, caused by municipal sewage effluent to the Caspian Sea.

Conclusions

1. The municipal sewage treatment in Baku for the industrial water supply of the Apsheron Peninsula will allow reduction of the consumption of deficiency fresh water and to stop the further pollution of the Caspian Sea.

2. The treated municipal sewage will be used as a water supply source in circulating water systems and technological processes of such industries branches of the Apsheron Peninsula, where water is widely used: oil-refining, oil-chemical, chemical, in the production of constructural materials etc.

3. For treated sewages to be used for industrial needs, they must correspond to technical water demands. According to the suspended materials demands, COD and BOD total, biologically treated municipal sewage must be additionally treated.

4. The experimental investigations were carried out on additional biologically treated sewage in Baku in biological ponds and in the rapid sandy filters (with and without aeration), which allows the determination of the main technological parameters of the above-said constructions.

5. Specialists from the Institute of the Microbiology, Virusology and Hygiene of the Azerbaijan Health Department, studied sanitary fitness of additionally rapid sandy filters and they recommended using the decontamination of sewage under the condition of the residual active chlorine content is not less than 1.5 mg/l.

6. The economic factor of the additionally treated sewage usage on the first stage will be determined by the damage, caused to the Caspian Sea by municipal sewage effluent. ☐

Water Quality Indices	Additionally treated sewage in Baku		Sea water	Fresh technical water	Cooling water quality standard according to CMEA *	Circulating water supply system standard in USA
	in biological ponds	on sandy filters				
Temperature, °C	no 30	no 30	no 28	20	25-28	..
pH	7.5-8.5	7.5	7.5	7.4	6.5	abnormal
Suspended materials, mg/l	8-10	5-10	30-50	20-30	10-20	..
Carbonate hardness, mg-equiv./l	4.5	4.5	3.5	3.7	1.2-2.5	..
Alkalinity, mg-equiv./l	5.2	5.0	3.9	no determ.	no determ.	$HCO_3$0, 4 mg-equiv
Salt content, mg/l	no 1500	no 1500	12600	12500	up to 2000	500 24 mgl
BOD_5, mg/O_2/l	..	..	..	5	5	..
BOD_{total}, mg/O_2/l	4.5	5-8	10-30	8	..	..
COD, mg/l	50	55-60	20-100	28	..	75
Ammonia nitrogen, mg/l	5	15	0.1-0.5	..	30	..
Phosphates, mg/l P	0.6	1.0	traces	..	4	..
Iron, mg/l	0.1	0.1	..	8	1.4	0.5
Ca, mg-equiv./l	3-4	3-4	17	1.2-5.5	up to 7	2.6
mg/l	60.12-80.16	60.12-80.16	340	24-100	140	50
Mg'', mg-equiv./l	3.8-4.4	3.8-4.4	60	0.7-3.7	..	abnormal
mg/l	46.2-53.5	46.2-53.5	750	8.45		
SO''_4, mg-equiv./l	7.3-10.4	7.3-10.4	65	0.63	up to 10.4	4.1
	350-500	350-500	3080	28-128	500	200
Cl', mg-equiv./l	4.5-11.2	4.5-11.2	147	4-11	up to 9.8	14.1
	160-480	160-400	5400	130-370	350	500

* Council of Mutual Economic Aids

Table 3
The comparison between different kinds of water quality and technical demands

Water Reclamation as a New Dimension in Growth for Los Angeles

By Donald C. Tillman
City Engineer, City of Los Angeles, California, USA

Introduction

Throughout history the greater cities of the world have been located on rivers or near major sources of fresh water. The exception to this general rule appears to be the cities in Southern California, particularly my City of Los Angeles.

Located essentially in an arid, desert-like area, Los Angeles somehow grew from a small village to the third largest city in the United States. I was there because I was a native son; however, millions of others came because of the attraction of growth in a new land rich in resources, agriculture, and living conditions. That is *why* California became the most populated State in the United States, and Los Angeles sprawled dimensionally outward into a major metropolitan region. *How* this happened without a nearby water supply source and the dependency of growth on the development of water reclamation are the basic ideas to be discussed in this paper.

History of Water Supply in Los Angeles

The Los Angeles River has served as a flood control channel, rather than provide water for the people of a growing Los Angeles because it is concrete-lined and dry most of the year. It reaches from the Pacific Ocean to the western edge of the San Fernando Valley. Groundwater resources proved inadequate and civic leaders at the turn of the century realized that water was the key to survival of economic progress and creation of a major city. A dream to bring water from the snows of the Sierra Nevada Mountains was a reality by 1913. The Los Angeles Aqueduct System now brings water of excellent quality about 338 miles (544 km) from the Owens Valley. Today the quantity exceeds 410 million gallons per day (1,550,000 cubic meters per day) or 80% of the total supply.

Groundwater sources account for over 14% of the City's supply. The central basin in the metropolitan area contains 23 smaller cities which obtain a substantial portion of their required water by pumping directly from the Basin. Overdraft of groundwater twenty years ago caused recession of groundwater levels, resulting seawater intrusion, and resulted in a control being placed on groundwater withdrawals.

In 1927, the California State Legislature authorized the formation of the Metropolitan Water District of Southern California. It was initially comprised of Los Angeles and twelve other cities to construct and operate an aqueduct to import Colorado River water. In 1931, the thirteen cities approved a $220,000,000 bond issue to finance construction of the aqueduct. In 1941, after approximately eight years of construction, the 300-mile (483 km) Colorado River Aqueduct system was placed in operation. The District serves approximately 120 cities and many unincorporated areas in six Southern California counties. The total delivery to the southern California Coastal Plain is approximately one billion gallons per day (3,800,000 cubic meters daily).

The City of Los Angeles receives approximately 42 million gallons per day (159,000 cubic meters/day) of Colorado River water which represents only 11% of the City's preferential water right, leaving a substantial reserve entitlement. However, it has become apparent that the average flow of the River is insufficient to meet future demands of planned water projects of States in the Colorado River Basin, such as Arizona. The U.S. Supreme Court case of Arizona versus California in 1964 resulted in the long range reduction in California's right to Colorado River water from the original entitlement of 1,200,000 to 550,000 acre-feet per year. Los Angeles is only 2.5% dependent on this source.

In 1951, the California Legislature authorized the California State Department of Water Resources to construct the Feather River Project, later called the State Water Project. The purpose of the project was to convey surplus water supplies in the northern portion of the State to areas of deficiency in central and southern California. The project was also designed to provide flood control capabilities, power generation, recreation, salinity control in the Sacramento River Delta and enhancement of fish and wildlife habitat.

Construction of the approximately $2.8 billion State Water Project was begun in 1957 and is presently nearing completion. Major facilities of the project include 21 dams, 6 hydroelectric power plants, 22 pumping stations, and canals, tunnels and pipelines totaling a length of about 700 miles (1127 km).

The first water from the State Water Project was delivered in 1972 to Castaic Lake, a terminal reservoir of the Project, located about 15 miles north of the Los Angeles northwest city limits. This has amounted to over 3% of the water imported, until this year of the northern California drought.

Weather conditions in the United States have been extremely unusual. Heavy snows of the winter and rainfall throughout the year have been severe on the East Coast. Meanwhile, the West Coast has been experiencing the worst drought conditions in decades. Water conservation measures have been put into effect by many of California cities, including Los Angeles. Therefore, we have reached our limit in expecting increased quantities of water import from the described distant sources—the High Sierra, Colorado River, and Northern California—which are as far away as Los Angeles dare search for water without depriving other areas of of their water and their right to grow. A great deal of energy must be expended in the transport of our water supply.

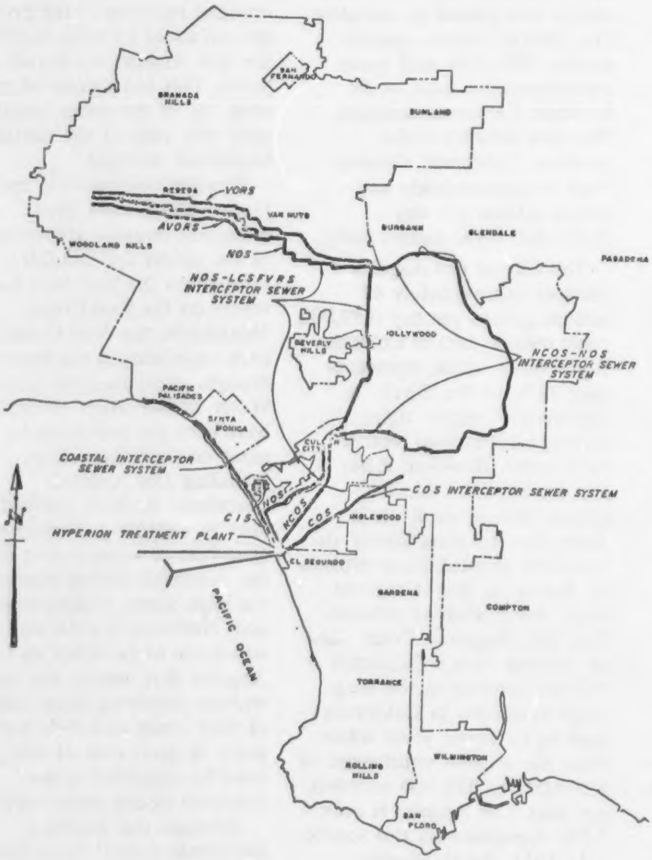
Between the southern California coastal basin and two of the major water supply sources for Los Angeles stand mountains that rise high above sea level. Before it reaches our basin, water from these faraway sources has to be pumped over those mountains.

The job lifting our water as high as 2,000 feet (610 meters) at a time is done by giant pumps located at strategic points along our aqueducts. Running these pumps takes the energy equivalent of five million barrels of oil a year: enough to meet the needs of a city of 250,000 for one year. Regrettably, after all this effort to bring the precious water resource to the people of Los Angeles, it has been used once, processed through sewage treatment plants and wasted in the Pacific Ocean. It was obvious that water reclamation from our readily available wastewater sources was the next important step and new dimension for the future of Los Angeles water history.

The Los Angeles Sewerage System and the Reclamation Potential

An understanding of the present City sewerage system is important to the development of a reclamation plan that would support wastewater reuse. The potential for this use is also discussed herein.

The City's major wastewater treatment facilities are the Hyperion Treatment Plant, the Terminal Island Treatment Plant and the Los Angeles-Glendale Water Reclamation Plant, the locations which were shown in Figure 1. The City also operates two minor facilities; the Los Angeles Zoo Treatment Plant and the Valley Settling Basin. In addition, the City of Burbank owns and operates the Burbank Water Reclamation Plant, which is tributary to the Los Angeles System.



Major interceptor sewer systems within the Hyperion system

The existing Hyperion Treatment Plant (HTP) is by far the largest treatment facility in the City area and can provide primary treatment for an average flow of 420 mgd (1,587,600 m^3/day). In addition, secondary treatment is provided for approximately 100 mgd (378,000 m^3/day). The plant basically consists of pretreatment, primary and partial secondary treatment, sludge treatment and discharge to Santa Monica Bay.

Pretreatment consists of mechanically-raked bar screens and horizontal flow grit chambers. After pretreatment, headworks effluents enter the primary sedimentation tanks. The plan has 12 primary sedimentation tanks which are equally divided into three batteries: East, Central and West. The average detention time is approximately one hour and twenty minutes.

The activated sludge process in the secondary treatment system treats 100 mgd of primary effluent. There are 32 aeration tanks in the system providing an average detention time of eight hours.

All primary sludge, waste activated sludge, grease and other flotables are pumped to the digestion system which consists of 18 tanks, 12 primary and 6 secondary. Following digestion, the digested sludge is screened and pumped through the seven mile, 20-inch-diameter (50.8 cm) outfall. The outfall extends to the head of a submarine canyon at a depth of 320 feet (97.5 m).

The primary and secondary effluent is pumped through the five-mile long, 22-foot diameter ocean outfall. The outlet consists of two identical 4,000-foot long diffuser legs in 200 feet of water (61.0 m).

The Terminal Island Treatment Plant (TITP) is located on Terminal Island in the Los Angeles Harbor area. The plant is presently being upgraded. The treatment processes consisted of pretreatment, primary sedimentation, sludge digestion and drying, and discharge of the effluent to the Los Angeles Outer Harbor to a point approximately 450 feet (137 m) offshore via a 39-inch (1.0 m) diameter outfall.

The secondary treatment facility at TITP, currently under construction, is now partially operational and will provide secondary treatment with an average capacity of 30 mgd (113,000 m^3/day). Sludge will will be discharged to sludge drying beds for subsequent disposal to a sanitary landfill. The TITP will be equipped with a remote monitoring and control system. The system will make it possible for the operator(s) to monitor and/or perform many functions from one location. The plant will also be supplied with flow metering systems, dewatering equipment controls, automatic sampling system and stand-by power.

Before a reclamation project is implemented, a number of factors must be examined. In a study conducted by the California Department of Water Resources and included in its Bulletin No. 80-5 entitled, Reclamation of Water from Wastes in Southern California, several important factors were summarized in the following questions:

a. How much wastewater is available?

b. Does the effluent meet the quality requirements that have been set for the intended beneficial use?

c. What will be the impact upon the environment on the use of this water?

d. Is this water reasonably competitive in cost with other supplies?

e. What are the legal constraints governing appropriation of reclaimed water?

f. Will the public accept use of the reclaimed water for the intended beneficial purposes?

g. Can reclamation be handled by existing agencies?

Keeping the above factors under consideration, the City's intent is to construct only those facilities necessary to provide for confirmed cost-effective and financially feasible reuse projects and only after the demand develops provide for the required treatment of any remaining wastewaters which are to be discharged to receiving waters.

Water quality does give Los Angeles some important advantages toward reuse.

The water delivered from the Owens River area is of excellent quality. The average total dissolved solids (TDS) from this source is approximately 214 mg/1. In 1974, the TDS averaged 171 mg/1 while the total hardness was 78 mg/1. This high quality of water is expected to remain relatively constant in the future.

The TDS of the Colorado River supply averages 743 mg/1. Water quality from this source is expected to decline in the future.

The quality of water obtained from the Feather River lies midway between that of the Owens River and Colorado River supplies. During 1973-74, TDS from this source averaged 322 mg/1 while hardness averaged 160 mg/1. It is expected that this water quality will improve in the future.

The major groundwater basins in the study area provide water of moderate quality. Although some wells yield hard to very hard water with TDS values approaching 1,000 mg/1, generally, groundwater lies within United States Public Health Service limits for drinking water.

Water consumption varies greatly from the coastal communities to the inland valleys. The present consumption in the City of Los Angeles is 181 gal./capita/day (685 litres/capita/day). Future water consumption may depend on the amount of sewer service charges, water pricing, and possibly legislative actions restricting water use.

Water imported to the study area in the future will probably improve in quality as State Water Project water is increased while Colorado River water supply is reduced. It is estimated that TDS values for groundwater will increase in the future in the San Fernando Basin.

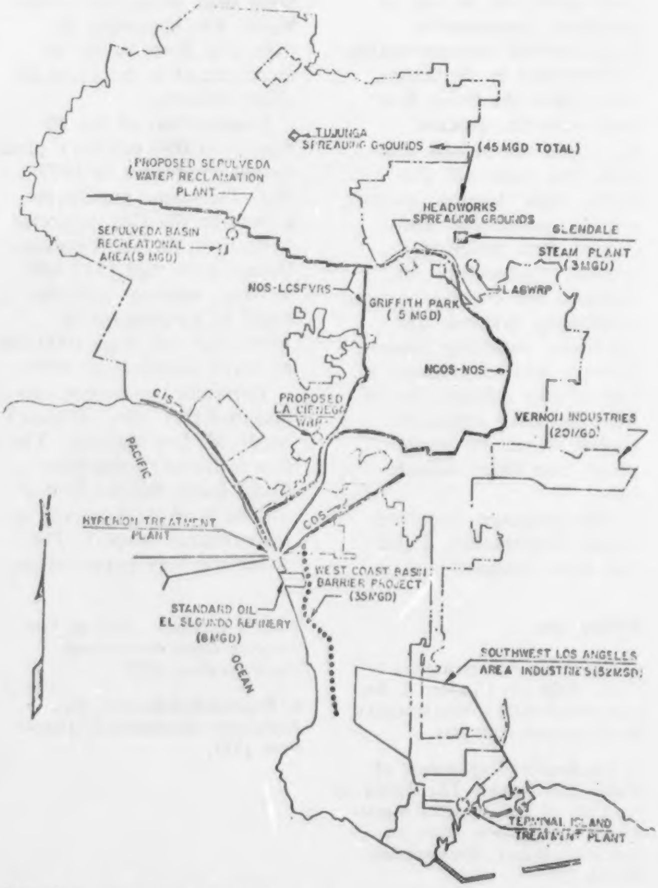
An ongoing study by the City's Department of Water and Power (DW&P) indicates that a reuse potential of 177 mgd exists that could hypothetically be supplied by the Hyperion system. The categories of reuse proposed in the study include groundwater recharge, industrial cooling and other industrial uses, landscape irrigation, seawater intrusion reduction, and miscellaneous recreational uses. The 177 mgd figure may be somewhat of an over-estimate since some of the potential reuse sites are located outside of the City of Los Angeles and, therefore, may be served with reclaimed water from the Los Angeles County Sanitation Districts, which surrounds Los Angeles. A decision as to who will serve these markets has not been made.

As shown in Figure 2, the potential reuse sites are not confined to the City limits of Los Angeles. Potential industrial markets, for the most part, are located outside the City limits. The DW&P would plan to sell reclaimed water to local water purveyors currently supplying those users with domestic water who in turn would supply the particular industries. The evaluation of the cost of reclamation would have to consider the negative impact on the revenue of the water retailers. In addition, any reclamation activities planned would also have to be compatible with the reclamation proposals of the Sanitation Districts of Los Angeles County, since the same markets are being considered by both.

The identified potential users of reclaimed water from the various treatment plants are:

Groundwater Replenishment by Spreading on Surface	
Department of Water and Power Headworks and Tujunga Spreading Grounds	45 mgd (171,000 m^3/day)
Subtotal	45 mgd (171,000 m^3/day)
Seawater Intrusion Barrier Supply	
West Coast Basin Barrier Project(a)	35 mgd (133,000 m^3/day)
Subtotal	35 mgd (133,000 m^3/day)
Industrial Water Supply	
Standard Oil Refinery(b)	8 mgd (30,300 m^3/day)
Southwest Los Angeles Area Industries(b)	52 mgd (197,000 m^3/day)
Vernon Industries(b)	20 mgd (75,800 m^3/day)
Glendale Steam Plant	3 mgd (11,400 m^3/day)
Subtotal	83 mgd (315,000 m^3/day)
Recreational Area Irrigation	
Griffith Park	5 mgd (19,000 m^3/day)
Sepulveda Basin Recreation	9 mgd (34,000 m^3/day)
Subtotal	14 mgd (53,000 m^3/day)
Total	177 mgd (671,000 m^3/day)

(a) Imported water now being used.
(b) Industry primarily outside Los Angeles City limits.


TUJUNGA SPREADING GROUNDS
(45 MGD TOTAL)
PROPOSED SEPULVEDA WATER RECLAMATION PLANT
HEADWORKS SPREADING GROUNDS
GLENDALE STEAM PLANT (3 MGD)
SEPULVEDA BASIN RECREATIONAL AREA (9 MGD)
NOS-LCSFVRS
GRIFFITH PARK (5 MGD)
LABWRP
NCOS-NOS
C/S
PROPOSED LA CIENEGA WRP
PACIFIC
VERNON INDUSTRIES (20 MGD)
COS
HYPERION TREATMENT PLANT
WEST COAST BASIN BARRIER PROJECT (35 MGD)
STANDARD OIL EL SEGUNDO REFINERY (8 MGD)
OCEAN
SOUTHWEST LOS ANGELES AREA INDUSTRIES (52 MGD)
TERMINAL ISLAND TREATMENT PLANT

Potential uses of reclaimed water

The plans for reclamation finally resulted in an upstream plant. The Los Angeles-Glendale Water Reclamation Plant (LAGWRP) will be the City's first operational water reclamation facility and is designed to provide tertiary treatment for a flow of 20 mgd (75,600 m³/day). The processes will consist of pretreatment, primary, secondary and tertiary treatment (chlorination and filtration). All settled solids and waste activated sludge will be returned to the North Outfall Sewer (NOS) for centralized solids processing at the HTP. The facility will normally be operated on a constant flow basis utilizing the standard rate activated sludge process. The design of the plant allows operation of discrete blocks of process units. In-plant process by passes are not provided for the primary, secondary or aeration units since all of the units would not be out of operation concurrently. Computerized instrumentation, incorporated in the design, will control the flows, flow measurements, process regulation and record vital data. The plant will also utilize data logging systems, remote monitoring and control, flow metering systems, conductivity, pH, turbidity and dissolved oxygen monitoring systems, and automatic sampling system. Tertiary treated effluent, a high quality effluent, can be used for park irrigation, cooling waters for steam plants and other suitable uses.

The proposed Sepulveda Water Reclamation Plant has been designed and is ready to go to construction. It is located in the San Fernando Valley in a residential area and will use the reclaimed water in an extensive Japanese Garden and park complex. Other uses of the reclaimed water will be on golf courses and other recreation areas.

The plant would be designed to handle diurnal flows averaging 40 mgd (151,000 m³/day) and a dry weather peak flow of 71 mgd (268,400 m³/day). In addition to primary and secondary treatment, the effluent to be discharged to the Los Angeles River and also would receive tertiary treatment consisting of filtration and chlorination. Solids removed during the treatment process would be returned to the sewer system for processing and disposal at the HTP.

The plant would be designed to withstand inundation from a 100-year flood stage in the Sepulveda Basin. The capability of bypassing flows would be incorporated in the event of plant failures.

Construction of the 40 mgd (151,000 m³/day) plant should commence in 1977. With the major population growth in the City projected to occur in the San Fernando Valley, a 30 mgd (113,400 m³/day) modular addition could be constructed in 1980, and a 15 mgd (000,000 m³/day) addition in 1993.

There are two unique uses proposed for the reclaimed water of Los Angeles. The first is found in the West Coast Basin Barrier Project located near the Los Angeles International Airport. The water use was estimated at 30 mgd (113,700 m³/day) to hold off the intrusion of seawater into the subsurface coastal plain water supply. The feasibility project was abandoned in 1974 when the Replenishment District decided that the monetary requirements of a reclaimed water supply totaled $44 to $50 per million gallons (3,780 m³/day) could not compete with the use of imported fresh water. However, present fresh water shortages may cause another try at this use.

The second proposal is theoretically sound, but it will be difficult to organize all the agencies and factors involved. It involves the TITP at the Los Angeles Harbor and the use of its treated water to heat the cold discharge from a proposed Liquefied Natural Gas (LNG) plant. The blending of the two discharges would provide an environmentally protective solution. Also, the nearby fish canneries discharge 3.3 mgd (12,500 m³/day) of water used in their processes. It is believed that a combination of discharge needs could produce a common solution of benefit to all.

Los Angeles must approach the future on this note of maximizing benefits, if the water needs of our growing population are to be met. The application of reuse for industrial purposes may not be as rapid as elsewhere, however, it is inevitable, and we shall make our professional contribution to new designs as we advance in our "new dimension" of reclamation. □

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The Peculiarities of Municipal Sewage Effluent Utilization in Industrial Plants

By Dr. Eng., prof. Lukinih[*] N.A.

The limited supplies of fresh water and its uneven distribution on the territory of this country in conditions of continuous common water consumption increase determine a necessity of looking for ways of economical and rational fresh water utilization.

One of the directions of solving this problem is utilization of municipal sewage effluent in technical water supply of industrial plants. Such an utilization of municipal sewage is undoubtedly particularly important for areas, already suffering from sharp water deficiency. However, lately, in connection with the development of so-called "endorheic" system of industrial complex water economy, the necessity of municipal sewage effluent inclusion for filling up irretrievable water losses is arising.

It goes without saying, that requirements on municipal sewage treatment degree are determined by technology of the plants where that is made from, which in turn causes a variety of possible flow sheets, methods, and buildings of this sewage treatment. There will prove to be a number of cases that requirements on quality of water, making for water reuse, can be far lower than that of discharging this water in a water body. In spite of the fact that industrial plants are permanent and large water consumers, utilization of municipal sewage effluent in technical water supply poses certain difficulties, connected with its composition changeability, bacterial contamination and inclusion of biogenous elements in quantities.

Bacterial contamination may be characterized by b.coli index, which usually does not exceed 10,000 units for municipal sewage secondary effluent. It proves principal possibilities of utilization such as sewage on condition its after-treatment, based on principals used in water supply technique with obligatory disinfection.

The most expedient is municipal sewage effluent utilization in recirculating cooling water systems. In this case the water must have definite temperature and does not cause formation of salt sediments on heat exchanger surface and in pipelines, does not cause metal and concrete corrosion and does not promote biological growth development. The absence of direct indices of chemical composition of water, characterizing thermal and corrosion stability and to a certain degree an ability to biological growth and also mutual influence of separate components to indicated water properties do not allow direct estimation of a composition of municipal sewage effluent in this relation. Indirect indices of such an estimation can be carbonate hardness, alkalinity, pH, BOD, oxydability, total salt content data.

The analyses of aforesaid indices of municipal sewage after its biological treatment proves that natural water composition after public utilization changes in first turn at the expense of BOD, oxydability, phosphorus and nitrogen compound contents, suspended solids, mineral salts increase, while pH, alkalinity and carbonate hardness may be kept at the previous levels. That is why corrosion and thermal stability of municipal sewage secondary effluent, in general, are determined by natural water initial properties[1]. Moreover, the practice of municipal sewage secondary effluent utilization in cooling systems of industrial plants indicates that presence of organic substances in it, small concentrations of surfactants and ammonium salts in concentrations according to stechiometric equilibrium with calcium bicarbonate causes stabilizing action. However the presence of soluble phosphorus compounds in municipal sewage and also ammonium nitrogen in higher concentrations, than indicated, particularly, at BOD loading higher than in natural water may promote biological growth increase.

By VNII VODGEO data (2), not free chlorine, but chloroamines being developed by chlorination are the most efficient from the point of view of biological growth prevention and, consequently, on condition of good suspended solids and organic pollutants removal, municipal sewage may be successfully used as additional water in recirculating water systems of industrial plants.

There are requirements on cooling water quality of recirculating water systems, developed by water authorities of countries-participants of Council of Economic Assistance in the table (3).

The experiments by Municipal Water Supply, Water and Sewage Treatment Research Institute of the Academy of Municipal Economy showed that these requirements can be satisfied if municipal sewage secondary effluent is additionally filtered through sand filters and is chlorinated in the completion stage. The chlorination is simultaneously the means of sewage disinfection and of struggle against biological growth (4).

The dual-layer filters and upflow filters are practised in this country for tertiary treatment of municipal sewage. The upper layer is crushed antracite with particle size 1-2 mm, and the lower layer is quartz sand with particle size 0,8-1,4 mm with height of

Indices of cooling water quality	UNITS	Temperature of product being cooled or of wall °C		
		to 80	80-400	above 400 (with fire heating)
temperature	°C	25-28	28-40	40-45
suspended solids in additional water	mg/l	10-20	10-20	10-20
ester soluble solids	mg/l	to 20	10-20	10-20
odour	points	to 3	to 3	to 3
colour	platinum--cobalt scale	no rates		
pH		6,5-8,5	6,5-8,5	6,5-8,5
total hardness of additional water	mg-eq/l	to 7	to 5	to 5
carbonate hardness of additional water	mg-eq/l	to 1,5-2,5	to 1-2	to 0,5-1,5
salt content of recirculating water	mg-eq/l	to 2000	to 1300	to 8800
chlorides in recirculating water	mg/l	to 350	to 350	to 150
sulfates in recirculating water	mg/l	to 500	to 600	to 250
total iron in recirculating water	mg/l	1-4	0,5-2	0,5-1,5
permanganate oxydability in additional water	mg/l	to 20	to 20	to 20
BOD_5 in additional water	mg O_2/l	to 5	to 5	to 5
phosphates (P_2O_5) in additional water	mg/l	to 4	to 2,5	
total nitrogen	mg/l	to 30	to 30	

each layer of 0,5 m in dual-layer filters. The filtration rate is 9-11 m/h. The backwashing is carried out by filtrated sewage liquor with intensity of 15 1/sec. m^2. The filters are equipped with surface washing systems for prevention of deposit formation.

The upflow filters are usually bedded with quartz sand of 1,2-2 mm particle size on height about 1,5 m and are equipped with water-air backwashing system of lower (horizontal) water draining. The intensity of air feeding is set in a range of 18-22 1/sec. m^2, and of water (at the end of backwashing) - 6-7 1/sec. m The filtration rate is 9-10 m/h.

The definite difficulties arise on chlorine dose appointment. Proceeded from experience of recirculating water supply system exploitation (without use of good treated municipal sewage) it is recommended to sustain residual chlorine concentration in water at a level of 1 mg/1 for struggle against biological growth (5).

The same concentration of residual chlorine was confirmed by VNII VODGEO experiments (2) when using secondary treated and additionally treated in sand filters sewage of Moscow for supplement of recirculating systems. For all that, by changing a multiplicity of water evaporation and its temperature in recirculating system, by controlling bacterial contamination of additional and recirculating water by quantity of saprophytes and b.Coli-index, it was shown that by increase of multiplicity of evaporation of recirculating water the saprophyte quantity grew while that diminished by water temperature increase. The viability of bacillus Coli fell by increase of multiplicity of evaporation and temperature increase. At residual chlorine content of 1 mg/1 the chlorination guarantees lowering of b.Coli index less than 1000.

It was shown by Municipal Water Supply, Water and Sewage Treatment Research Institute of the Academy of Municipal Economy (6) that effect of sewage disinfection considerably depends on continuance of contact with chlorine. So, at residual chlorine content of 0,45-0,5 mg/1 in sewage secondary effluent and at contact time of 1 hour, the more high efficiency of disinfection was achieved, than at residual chlorine content of 1,5 mg/1 and at contact time of 30 min. Nevertheless the specialists in hygiene of water (7) recommended to keep quantity of residual chlorine in water not less than 1,5 mg/1 with contact time 30 min., that is they maintain requirements analogous to that to disinfection of municipal sewage discharge into open basins.

In some cases, especially in southern areas of this country, the additional treatment of sewage secondary effluent is carried out in oxidation ponds, mainly with natural aeration. The advantages of the method are evident from the point of view of disinfection, but nevertheless when using such water in recirculating water supply the necessity of suspended solids removal and chlorination remains. The latter is required for biological growth control. In this case both granular bed filters and microstrainers can be used for suspended solids removal.

Considerable public use of synthetic surfactants leads to increasing of easily absorbed by microorganisms phosphorus compound content in municipal sewage secondary effluent. Approximate increase of phosphorus compound content is 1,6 g/24h per capita on P_2O_5 at the expense of surfactants in domestic sewage. The phosphorus content in municipal sewage secondary effluent, undoubtedly, is considerably ranged and depends both on water draining rate, correlation between domestic sewage and industrial wastewater, and on flow sheets of aeration tanks. At an average it is equal to 8-15 mg/1 on P_2O_5.

The phosphorus removal from sewage can be carried out by "simultaneous" sedimentation method or by introducing the chemicals (ferric sulphate, aluminium sulphate) before secondary clarifiers or directly before filters. In the last case the filtration rate must be lowered to 6-8 m/h.

The economy of municipal sewage reusing is determined in general by costs for aftertreatment and for transport to consumer.

When reusing aftertreated municipal sewage in industrial water supply the attention should always paid to creation of conditions, guaranteeing prevention of possible infection transmission. It necessitates setting of regime and control of aftertreatment units processing at sewage treatment plants close to regime and control of domestic and drinking water-supply and at industrial plants—creation of conditions when water contact would be minimized for workers. □

Reuse of Process Water from a Large Steel Plant

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The Metropolitan Sanitary District of Greater Chicago is a Municipal Organization that services an area of approximately 2243 sq. kilometers (866 sq. mi.), all in Cook County, Illinois. The District serves the City of Chicago and 124 other outlying municipalities including a population of approximately 6,000,000 people. The primary service performed by the District is the collection and treatment of combined municipal and industrial wastewater which averages 5.1 million cu. meters each day (1350 MGD). The area includes in excess of 13,000 business and industrial concerns. At the present time it is estimated that industrial waste constitutes less than 15% of the load on the system.

On September 18, 1969, Chicago Sanitary District Officials passed an Ordinance which prohibited the discharge of sewage, industrial waste, or other waste of any kind into the waters of Lake Michigan.

As a result of this Regulation, seven potable water plants on Lake Michigan in the jurisdiction of the District were required to cease discharge of their sludge to the Lake and all industries were required to stop waste discharge to the Lake.

The most significant industrial dischargers were five steel mills. One of the five mills discharged directly to the Lake, the remaining four discharged into the Calumet River which normally flows away from the Lake but can flow into the Lake during any heavy rainfall.

Studies were made of water quality and lake bottom characteristics. The studies revealed gross water pollution caused by discharge of oils and greases, cyanides, phenols, iron, suspended solids and ammonia. These polluting materials were also present in lake bottom sediments in the vicinity of plant outfalls.

As a result of court action, four of the steel plants have installed or are committed to the installation of water reuse systems and the fifth, while still discharging into the waterway system has installed rapid sand filters and cyanide destruction systems. Efforts are continuing to eliminate all discharges from the waterways.

The amount of wastewater discharged from the steel plants has been reduced to 450,000 cu. meters (119 MG) a day from the 2.1 million cu. meter (546 MG) daily total in 1969.

The number of sewers discharging wastewater from the steel plants has been reduced from 45 to 13 as well. Due to the Sanitary District's Sewage and Waste Control Ordinance enforcement activities and the area steel plant's cooperation, the discharge of major pollutants has been significantly reduced—by more than 90%, see Table I.

PARAMETER	PRIOR TO RECYCLING	AFTER RECYCLING	% REDUCTION
Suspended Solids	75,300 (166,000)	1220 (2690)	98
Iron	11,300 (25,000)	57 (235)	99
Ammonia	2,300 (5,150)	43 (95)	98
Oil & Grease	17,900 (39,500)	156 (343)	99
Phenols	122 (268)	3 (7)	97
Cyanide	171 (376)	17 (37)	90

Table I.
Pollutants Discharged—kg/d (lb./d)

This paper will describe the recycle system installed by the United States Steel Corporation, South Works, the only Chicago steel mill that discharged directly into the Lake. The system, costing approximately 30 million dollars, is typical of the recycle systems installed by the other mills except that South Works does not have a coke plant at this location. Annual operating expenses of the system are approximately four million dollars with approximately 1/3 of this cost being for energy.

Production Facilities

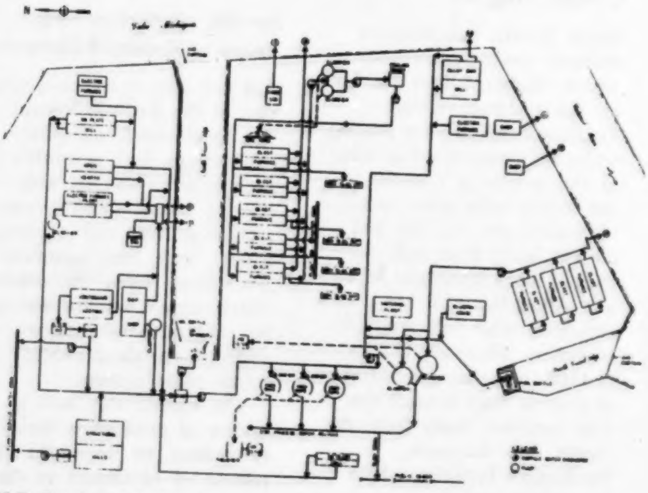
U.S. Steel Chicago South Works is located on the shores of Lake Michigan at the mouth of the Calumet River in Chicago, approximately 21 km (13 miles) south of the downtown area. It occupies 232 hactare (573 acres) of land. It has 3.6 km (2.25 miles) of lake and river frontage and 2.25 km (1.4 miles) of dock space provided by its north and south vessel slips. The north slip runs east and west and connects on the east with the Calumet Harbor portion of Lake Michigan. The south slip connects with the Calumet River approximately 760 m (2500 feet) west of its mouth.

It is the largest steel producer in the State of Illinois, the second largest plant owned by United States Steel Corporation and the sixth largest in the United States. In the same general industrial area the plants of Interlake Steel, Wisconsin Steel, Republic Steel, and Commonwealth Edison State Line Generating Plant are located. Farther to the south, in Gary, Indiana, are the steel making facilities of Youngstown Sheet and Tube Company, Inland Steel Company and another plant of United States Steel Corporation.

Construction of this plant began in 1880 and the first blast furnace operation commenced in 1881. There are now two groups of blast furnaces, the south line and north line. The south line consists of three older operable furnaces and the north line consists of four operable furnaces. There is a three-vessel Basic Oxidation Process (BOP) shop, two of which operate while the other is relined. It has three operating electric furnaces and no operating open hearth furnaces.

Primary mill facilities are a slabbing mill and two blooming mills. Finishing mils are a 244 cm (96 inch) plate mill, a 76 cm (30 inch) Universal plate mill, a beam mill, a structural mill, an alloy bar mill, and a four strand continuous bloom caster with in-line rolling to billets. The plant's latest addition is a modern high speed four-strand rod mill.

To support these steel producing facilities and rolling mills there is a sintering plant, a roll shop for making and redressing mill rolls, an air separation plant which produces oxygen for steel making processes and general mill use, three power stations generating electrical power and mechanical power for supplying blast air to the blast furnaces and pumping



U.S. Steel South Works
Chicago

plant service water, ingot stripping facilities to remove steel ingots from molds, a foundry for casting ingot molds, and complete maintenance facilities consisting of a machine shop, carpentry, welding, blacksmith, pipe, pattern, electrical repair, locomotive repair, masonry, and rigger shops. Although electrical power is generated on the site, by far the largest share of power is purchased from Commonwealth Edison. There are 42 km (26 miles) of sewers in the plant, considering only those which are 15 cm (16 inches) in diameter and larger, and 750 manholes. There are four unloading bridges on the north dock and three on the south. These facilities handle a total of about 5500 million kg (6 million tons) of raw materials per year. On an average day 15.9 million kg (17,500 tons) of ore and 3.0 million kg (3,300 tons) of limestone are used. Coke is delivered by railroad. Approximately 150 carloads of coke enter the plant each day, and 3.4 million kg (3,700 tons) of scrap are used every day.

The plant has three water intakes and prior to the recycle system pumps on an average annual basis 1.5 million cu. meter (400 MG) of process and cooling water per day.

General Water Quality Control Program

South Works has separate sanitary sewers, none of which discharge into the lake or the Calumet River. Treatment facilities for process water are constructed as close to the source as possible. All rolling mills were equipped with scale pits and the 244 cm (96 inch) Plate mill, 76 cm (34 inch) Structural Mill and Alloy Bar mill are equipped with belt type oil skimmers. There are two 49 m (160 feet) diameter clarifiers to process blast furnace flue dust scrubber water from the North line furnaces. Production facilities which required water recycle systems include: Blast furnaces, Basic Oxygen Process, Continuous Casting, Sintering Plant, Pig Casting, Electric Furnace, Structural Mill, and an Alloy Bar Mill. To remove and collect oil at the Structural Mill an American Petroleum Institute separator was installed to solve the past oil problems.

Construction of the recycle system was staged over a five-year period from 1971 until the end of 1975. Pollution Control work performed prior to 1971 had succeeded in substantially reducing both the volume and weight of pollutants contained in the waterway discharge as shown in Table II.

Year	Suspended Solids	Phenols	Cyanide	Oil	Ammonia Nitrogen	Discharge Volume 1000 cu.m/d (MGD)
1969	30,389(66,995)	47(104)	104(230)	7582(16,717)	1491(3287)	1113 (294)
1970	22,621(49,869)	24(52)	122(268)	6669(14,703)	601(1325)	988 (261)
1971	6,078(13,400)	4(8)	4(8)	1905(4,200)	200(440)	379 (100)
1974	CONSTRUCTION OF RECYCLE SYSTEM					227 (60)
1975	SS = 16 mg/1		Oil = 5 mg/1			132 (35)
1976	0	0	0	0	0	0

Table II.
U.S. Steel South Works Wastewater Discharge to the Waterway Average Annual kg/d (lb./d)

Completion of Step II on December 31, 1970, eliminated all waste discharge directly to the Lake but 378,500 cu. m (100 MG) of treated water was discharged to the Calumet River daily.

Specific Abatement Steps Taken to Reduce Pollutants

The first step of the construction of the Recycle System was to eliminate all cross connections that permitted process water to mix with cooling water. Cooling water recycle systems with cooling towers were then completed. Blow-down from the cooling water recycle systems was used for slag quenching or was added to the clean process water reuse system.

The second step was a review of production facilities to reduce or eliminate the release of pollutants to the process water system. A new lubrication system called "Minimum Lube" was initiated at the rolling mills which also helped to reduce the oil control problem. A total of 9 oil skimmers were installed at strategic locations in the rolling mill scale pits to remove oil from process water. The following Alterations were made to the plant sewer system to prevent the discharge of oil and other pollutants. The plant layout dipicts certain key facilities and flow streams.

Nos. 2 and 3 Outfalls

Approximately 213 m (700 feet) of 120 cm diameter (48 inch) sewer and 61 m (200 feet) of 76 cm diameter (30 inch) sewer were cleaned and a bulkhead installed to divert water from the 244 cm (96 inch) Plate Mill which formerly discharged to the North Slip through Outfalls 2 and 3, to the No. 5 diversion sump where it is now discharged into a recirculation basin. The twin outfalls, 2 and 3, now discharge only Power Station condenser cooling water.

Before the 244 cm (96 inch) Plate Mill water was diverted, a belt type oil skimmer was installed at this mill's scale pit to remove oil from scale flushing water.

No. 5 Outfall

Treatment facilities were constructed which divert the water formerly discharged at this outfall to the new central treatment plant, described below. These facilities now handle the process water from the No. 2 electric furnace shop, all rolling mills, BOP Shop, research facilities, foundry, and the sintering plant.

Some of the treated water from the central treatment plant is discharged as blowdown to the municipal sewer system. As the process water is recycled a build-up of dissolved solids occurs which, if not diminished, may hamper or prevent the operation of both production and waste control facilities. To avoid such build-up, relatively small amounts of a "once through" discharge system known as "blowdown", must be removed from the system and replaced by fresh water.

Treatment of blowdown by reverse osmosis/electrodialysis, ion exchange and evaporation was originally considered. Since technology has been demonstrated in the saline water conversion programs, multiple effect evaporation was given the most careful consideration. It was assumed that the brine produced, approximately 6600 cu. m/day (1.75 MGD), would be disposed of by deepwell injection at 42 kg/sq. cm (600 psi) well head pressure. Due to the large area and energy requirements for this distillation plant and the belief that the climate and geology in northern Illinois are unfavorable to deepwell disposal, discharge of the blowdown to the municipal sewer was ultimately approved.

The blowdown to the municipal sewer is restricted to 230 l/s (3,700 GPM) and can contain no more than 20 mg/l of suspended solids, 10 mg/l of oil, and 2,000 mg/l of dissolved solids. The annual average blowdown of the completed system is 132 l/s (2,100 GPM).

The blowdown must also comply with limits established for all trade waste discharged into the sewers as shown in Table III.

Waste (Chemical)	**Concentration (mg/l)**
Boron	1.0
Chromium (Total)	25.0
Chromium (Hexavelent)	10.0
Copper	3.0
Cyanide (Total)	10.0
Iron	50.0
Lead	0.5
Nickel	10.0
Temperature not over 150°F (65°C) pH	4.5 - 10.0
Zinc	15.0
Cadmium	2.0

(Volatile, toxic, malodorous and radioactive materials are also prohibited.)

Table III.

Regulatory Limits for Pollutant Discharge to M.S.D. Sewer

With the changes outlined above, Outfall No. 5 now discharges only overflow storm water to the North Slip.

North Slip

An air curtain was installed across the mouth of the Slip to contain any oil discharged during the construction period. This facility consists of a 7.6 cm (3-inch) diameter pipe, on the bottom of the slip, drilled at spaced intervals to release the air forming the curtain. Two portable air compressors of 55 l/s (900 CFM) capacity each, supply the air, one of which is in service, while the other is on standby. Visual observation indicated that this facility is very successful in containing any oil present in the North Slip during the construction period from flowing into the Lake.

The discharge from No. 10 Outfall to the inner harbor was stopped by diverting the flow in its sewer to a new diversion sump. Prior to this change, efforts were made to reduce and improve the quality of the discharge flow to the inner harbor. The No. 10 sewer served the Alloy Bar Rolling Mill where a belt type oil skimmer was installed to recover oil from the scalepit. The No. 10 sewer also served the research facilities, Foundry and part of the South Line Blast Furnaces.

Approximately 274 m (900 feet) of 122 cm diameter (48 inch) sewer was cleaned and a portion of the No. 10 sewer flow was diverted to the two existing 49 m (160 foot) diameter Dorr clarifiers, reducing the discharge at No. 10 Outfall. The entire flow from No. 10 Outfall was then diverted by building a diversion sump and converting an existing concrete basin into a retention reservoir.

A major feature of the program was the construction of two 34 m (110 foot) diameter clarifiers to process the blast furnace flue dust wash water from the South Line Blast Furnaces before discharge to the Calumet River and massive piping changes to accommodate these new facilities. Vacuum filters were installed to further concentrate the underflow from the clarifiers.

Additional new facilities included a central pumping station, a central treatment plant, cooling towers and massive changes in interconnecting piping to accommodate the facilities. The process waters from the North Line Blast Furnaces are cleaned, cooled and recycled. All remaining process wastewaters except from the South Line Furnaces are pumped to the Central Treatment Plant. After treatment in this plant, they are discharged to the clean process water system or to the municipal sewer. The Central Treatment Plant consists of three high rate reactor clarifiers with a high solids recirculation rate. Chemicals, e.g., polyelectrolyte, which aid in the settling are added. Each clarifier is 38 m (125 feet) in diameter and 7.6 m (25 feet) deep at the sides. The minimum detention time provided in the clarifier is 96 minutes at 379 thousand cubic meters per day (100 MGD). The underflow from the reactor clarifiers goes to a thickener 20 m (65 feet) in diameter where the solids are further concentrated. There are four pumps to carry the wastes to the Central Treatment Plant, each with a capacity of 840 l/s (13,300 GPM). Three run at one time and the fourth is in reserve. In order to further assure against escape into the Calumet River of any oil which might be in the South Slip, an air curtain similar to the one described for the North Slip, was put into operation across the mouth of the South Slip.

Discharge of 11,000 to 19,000 cu. meter/day (3 to 5 MGD) from the Central Treatment Plant to the municipal sewer is the only process water dscharged by the plant.

A new surge tank to receive the treated effluent by gravity flow from the three reactor clarifiers was installed to account for various operation irregularities.

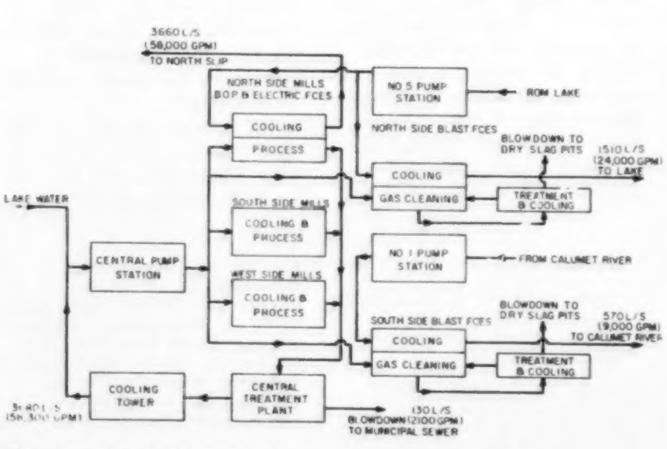
Effect of Steel Mill Blowdown on the Municipal Plant

The success of this recycle system depended completely on the ability and willingness of the local municipal treatment plant to accept blowdown from the system. The municipal plant is located on the Calumet River and is separated from the Lake by Locks. As a result, all municipally treated waste discharges to the Illinois River system and then down the Mississippi River to the ocean.

While the discharge of blowdown to the municipally owned Calumet Sewage Treatment Plant solved the problem for the steel mills, it caused a problem for the municipal plant.

All of the District's Plants have daily concentrations of cyanide in their effluent which exceed the Illinois Pollution Control Board (IPCB) effluent limit of 0.025 mg/l part of the time.

The Calumet Plant had the highest total cyanide effluent



U.S. Steel South Chicago Works
Wastewater Recycle System

concentraton of the three major plants which received industrial waste. Frequency data for daily effluent cyanide concentration are shown in Figure I.

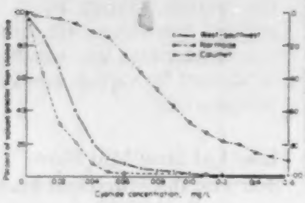


Figure I.
The Metropolitan Sanitary District of Greater Chicago. Cumulative Frequency Distributed for final Effluent Concentrations of Cyanide

The District's small treatment plants having no known industrial waste load, showed occasional cyanide effluent values which exceed the IPCB limit. (Figure II)

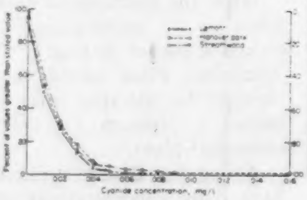


Figure II.
The Metropolitan Sanitary District of Greater Chicago. Cumulative Frequency Distributed for final Effluent Concentrations of Cyanide

Complex forms of cyanide in the effluent averaged 75% with 25% being simple forms of cyanide. The low concentration of simple cyanide contained in waterway samples downstream of the Calumet Plant are not considered toxic to existing or indigenous aquatic life. Regulatory agencies are considering a revision of the effluent limit from total cyanide to a new limit based on the simple or more toxic form of cyande.

Additionally, the recycle systems have contributed to a higher than normal effluent concentration of ammonia and phenols from the Calumet Sewage Treatment Plant (see Table IV). It is believed that tighter controls, together with a two-stage nitrification system scheduled for construction in the near future, will resolve these problems.

Facility		Ammonia	Phenol	Oil
Calumet	max.	27.4	0.107	79.
	avg.	16.0	0.010	15.
	min.	4.4	0.000	1.
West Southwest	max.	8.0	0.014	56.
	avg.	2.0	0.002	17.
	min.	0.0	0.000	2.
Northside	max.	13.3	0.043	19.
	avg.	7.1	0.005	3.
	min.	1.2	0.000	0.
John Egan	max.	8.2	0.027	15.
	avg.	0.4	0.003	3.
	min.	0.0	0.000	0.

Table IV.

Treatment Plant Effluent—1976 Data (mg/1)

Conclusion

Since the end of 1975, the plant has operated successfully while recycling all process water. The only discharge to the waterway is uncontaminated cooling water and storm water overflow. These flows are monitored regularly to insure that they do not become contaminated.

Elimination of all wastewater discharge to a water from a fully integrated steel plant has been demonstrated. Disposal of blowdown to a municpal wastewater plant is feasible provided the municipal plant is large enough and the blowdown quality is controlled.

It is technically possible to treat and dispose of blowdown through evaporative systems followed by deep well disposal of brine. In the Chicago area, this type of disposal system was not considered either economically or environmentally practicable. ☐

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Conditions of Municipal Effluents Use for Making-Up of Recycling Water Supply Systems

By S.P. Sukach, A.G. Kirichenko, I.B. Shenderovich, J.I. Antonchuk, Kharkov Devision of VNIIVODGEO.

One of the ways for solution of the problem of integrated utilization and protection of water resources against depletion and pollution is advanced treatment and repeated utilization of biologically treated municipal effluents for technological water supply of industrial enterprises.

Possibility of these waters utilization is determined by sanitary, technological and economical factors.

For some years the Kharkov Division of VNII VODGEO Institute has been elaborating designs of filters for advanced treatment of biologically treated municipal effluents and conditions of their utilization in systems of recycling water supply of industrial enterprises.

A filter has been designed which ensures high degree of effluents advanced purification from suspended solids and pollutants the degree of concentration of which is expressed by BOD value.

The filter is a tank of rectangular form divided by a perforated partition plate into two tiers. Lower tier is intended for removal of suspended solids, the upper tier is equipped with the system for delivery and distribution in granular filter media of air or oxygen. So, in the upper, aerated tier of the filter favorable conditions are created for fixed active forms of aerobic microorganisms—mineralizers of organic matters which remain in treated effluents in dissolved or colloidal form.

Studies of the filter operation made under pilot installation conditions showed that at a concentration of suspended solids in initial liquid equal up to 30 mg/l and BOD_{20} equal to 15 - 20 mg/l, filtering rate - 6 - 7 m/hr, aeration intensity for 1 hr - 1 m^3/m^2, intensity for I hr I m^3/m^2, duration of the filtration cycle of the lower tier - 24 hours and that of the upper tier - 70 hr, the filter operated efficiently and the concentration of the suspended solids has been reduced down to 5 mg/1, BOD_{20} value down to 3 - 5 mg/1.

The developed filter and method of biologically treated effluents filtering with simultaneous introduction of air or oxygen into the filtering media layer can have various design solutions:

two tier aerated granular filter, described above;

two tier aerated granular filter in which nonaerated and aerated parts of the filter are located near each other in horizontal plane. Direction of water flow in nonaerated part "upwards", in aerated one "downwards";

aerated granular filter combined with microfilters i.e., as the first stage for trapping of suspended solids microfilters are used with mesh dimensions equal to 40 - 45 Mm and filtering rate 25 - 30 m/hr;

All three alternatives of advanced treatment of effluents by aerated filters have passed design development stage and have been put into operation by a number of enterprises or introduced into design projects.

When solving the problem of tertiary treated water utilization main attention was paid to cooling systems since usage of water for cooling exceeds all other usages of water in industry.

Experimental works have been carried out on pilot installations, located at biological stations of several cities of the Ukraine.

Pilot installations incorporated units for advanced treatment of biologically treated effluents. Aerated granular filters designed by the VNII VODGEO, Kharkov Division, and three systems of recycled water supply were used. Each water supply system of the installation included all elements of industrial systems which made it possible to perform experiments on change of quality study as well as to study conditions of municipal effluents utilization with due account for difference in the temperature of water heating, heat loads of cooling surfaces, water flow velocities and degree of water evaporation.

Effluents of bological stations after complete biological treatment and advanced treatment on aerated granular filters had the following quality indices values:

pH	7.6-7.9
total alkalinity, mg-equiv/1, —	6.6-8.5
total hardness, mg-equiv/1,	7.3-8.5
calcium-ion, mg-equiv/1,	5.0-6.2
total salt content, mg-equiv/1,	670-980
chlorine-ion, mg/1,	150-250
sulphate-ion, mg/1,	100-280
phosphates, (P_2O_5-), mg-equiv/1,	0.7-3.5
ammonium nitrogen, mg-equiv/1,	12.5-18.0
nitrites, mg-equiv/1,	trace–0.96
nitrates, mg-equiv/1,	0.8-2.4
surfactants, mg-equiv/1,	0.3-1.0
suspended solids, mg-equiv/1,	up to 5.0
BOD_{20}, mg-equiv/1,	up to 5.0
COD, mg-equiv/1,	60-100

In order to secure sanitary safety of water it was subjected to chlorination up to Coli-titre 300. Chlorine dose has been determined by experimental way for water of each biological station and was equal to 7 - 10 mg/1 with residual chlorine content being equal to 1.0 - 1.5 mg/1.

The above-given data allow to conclude that quality indices of the waters, with the exception of alkalinity and hardness, to correspond the requirements for water used in cooling systems developed by water management authorities of member-countries of COMECON.

While determining the degree of these waters suitabiity for making up of recycling water supply systems it was necessary to elucidate the following questions: change of water composition in a cycle, tendency and intensity of scale formation, corrosive and biological activity.

Experiments on the installations have been done at operational parameters typical for water supply systems of a number of productions with tubular heat exchanging equipment at metallurgical, machine-building, power-producing and chemical industries plants. So, the temperature of cooled surfaces made up 100 - 500°C, temperature of water heating 40 - 60°C, evaporation factor from 1.5 to 3.0, velocity of water flow in heat exchangers pipes from 1.0 to 2.5 m/sec.

Analysis of the experiment results showed that quality indices values of recycled water at all investigated regimes differ from those for make up water. First of all this difference is expressed in growth of content, in accordance with evaporation multplicity, of nearly all salt forming components, increase of organic compounds content, total mineralization, change of pH value, alkalinity and dissolved gases concentration.

Calculation of recycling water saturation with calcium carbonates indicated over-saturation, the degree of which increases with growth of heat load of cooling surface, water heating temperature and evaporation factor. However, availability of organic matters may facilitate certain deceleration of scale deposits formation process.

At the same time, increase of concentration of chlorides, suphates, total salt content, as well as availability of dissolved gases indicates that these waters have certain corrosive activity.

For quantitative evaluation of the recycling waters stable properties, observations and monitoring of the processes of scale formation and metal corrosion were carried out on special samples made of steel pipes installed in heat exchangers of water supply systems.

As a result of execution of complete experiments on factors of 2^3 type, the following equations were received which depict the influence on these processes of the above-named operational parameters of recycling water supply cooling systems.

$$P'' = -3.738 + 1.286V - 2.290Ef + 0.1016t - 0.0356Vt - 0\S0639\,Ef$$

where: P'' — scale formation rate, mm/yr
V — water flow velocity, m/sec
t — water temperature, C°
Ef — evaporation factor

$$P = -0.1845 + 0.2848V - 0.0051t - 0.1017Ef + 0.0012tEf - 0.0031\,Vt$$

where: P — corrosion rate, mm/yr

These dependences are suitable for determination of rate of scale formation and metal corrosion during operation of recycling water supply cooling systems, with heat loads of heat exchangers equal up to $60 \cdot 10^3$Kcal/m^{2}hr, on biologically treated effluents analogous in their composition to the waters under study, in the temperature range of 40-60°C, water flow velocity equal to 1.5 - 2.5 m/sec, and evaporation factor of 1.5 - 3.0.

Since equations (1) and (2) are nonlinear, single-valued answer as to the influence of that or another factor on intensity of scale formation or corrosion rate is difficult to be obtained.

Graphic technological analysis of the obtained dependences may be done with help of their diagramatical interpretation, shown in Fig. 1 and 2.

In particular, from Fig. 1 it is seen that with the increase of temperature, scale formation intensity increases and the higher evaporation factor, the more apparently this dependency reveals itself.

With increase of water flow velocity the scale formation intensity decreases. However, main influence in the studied limits of factors fluctuation is exerted by temperature, therefore, in order that with the increase of water heating temperature, the scale formation intensity be unchanged, it is necessary to increase water flow velocity or decrease evaporation factor and, in some cases, to change both factors simmultaneously.

Graphs on Fig. 2 show that, at constant evaporation factor, with increase of water flow velocity and water heating temperature rate of corrosion grows up, with the former factor having higher influence on this process then the temperature. Increase of the evaporation factor reduces rate of corroson i.e., in this case the relationship is of inverse type. For example, in order that during increase of water flow velocity the corrosion rate value be unchanged, it is necessary to decrease water heating temperature or to increase evaporation factor.

So, developed mathematical models of scale formation and corrosion processes give not only qualitative characteristics of factors relationship but also enable to make quantitative assessment of the influence exerted by each of these factors on the function. Besides that, obtained equations help to select rational regime of recycling water supply systems operation.

For prevention of carbonate deposits formation, stabilizing treatment of make-up water, for example, by acidification method, is necessary. Acid dosages are determined depending on parameters of water supply system operation and temperature of cooling surfaces.

Results of the corrosive tests allow to recommend to employ metals, pump equipment, pipelines and fittings intended for freshwater systems of analogous purpose.

Dosage of chlorine, generally accepted for disinfection of water, secured prevention of biological growths.

Utilization of municipal effluents for making-up of recycling water supply systems facilitates rational use of water resources, reduces consumption of more expensive and less available water suitable for economic and domestic needs and also assists protection of water bodies against pollution. □

The Role of Wastewater Reuse and Process Loss Control in Paper Industry Wastewater Management

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Introduction

The point of departure for this symposium paper must necessarily be a brief review of the geseral objectives and tools of wastewater management in the paper industry. Hopefully this will provide a perspective within which to sift through the new technological developments related to (a) expanded internal reuse of waste process streams, (b) modification in production technology that involve additional opportunities for such reuse, and (c) efforts to minimize loss of process materials to external control systems in existing production technologies. Otherwise we run a risk of reviewing these developments with only their technological novelty in mind and without a proper appreciation of their potential role in improving wastewater management practice.

A. Characterization of Wastewater Management Objectives and Tools

(1) **Management objectives** — The wastewater management objectives as perceived within the industry can be simply stated as follows:

(a) to achieve and to assure the necessary level of compatibility between effluent discharge and beneficial receiving water uses, particularly for fish propagation, water contract recreation, and public drinking water supply purposes;

(b) to allow for the orderly growth of the industry at existing production sites and at new locations with progressively more restrictive water quality maintenance characteristics.

The wastewater management technology development objectives then are corollary to these overall objectives.

(2) **Management tools** — The tools available for wastewater management are multiple and can be classified into four categories, including (a) internal recycle and loss control, (b) external control technology applied to the residual load following internal measures, (c) recycle to process or to industrial water supply of the final product of external control technology, and (d) the findings of environmental science appled to the individual mill site, including regular environmental quality monitoring to assure that the beneficial uses are in fact adequately protected. The importance of the latter cannot be overestimated for both its problem definition value as well as its ability to document the adequacy of the control measures adopted. Finally, the need for, and value of, integrating the first three should be abundantly made clear to avoid the hazards of pitting each control approach against the others rather than seeking the optimal combination within the limits of available capital resources and with assured performance as a parallel objective. With this as background we cas proceed to an examination of the role of, and current developments in, wastewater reuse and process loss control.

B. Principal Elements of Internal Control and Effluent Reuse

The principal elements of internal control and effluent reuse can be differentiated as follows, recognizing that not all the technological approaches necessarily embrace all three elements.

(1) effluent volume reduction,

(2) general load reduction to external treatment, accompanied by some changes in specific composition,

(3) minimization of effluent variability both reaching and leaving external control facilities.

C. Objective and Potential Benefits of Internal Control and Effluent Reuse Programs

At least four (4) classes of objectives and potential benefits can be identified with these two internalized wastewater management approaches, discussed jointly in this paper. They are as follows:

(1) **Optimization of overall wastewater management costs and performance reliability** — To the degree that internal measures reduce the residual load requiring external treatment, they result in a lowering of external treatment costs. This is not accomplished without incurring significant costs in internal arrangements, so that the optimization goal must remain paramount. Since improvement in system reliability is also an objective it is conceivable that some overall cost increase can be justified if tangible improvements are realized in this area as well.

(2) **Avoidance of need for expansion of existing external control facilities** — Our industry has recently completed a major and accelerated program of construction of biological treatment facilities involving both space-intensive and high rate systems. We recognize that (a) application of in-process load control measures may have lagged besind this construction effort, (b) the program has carried a high price in both available capital and space resources, (c) further industry growth is anticipated at many of these mill sites, and (d) more restrictive site allotments of effluent load discharge are foreseen as a consequence of further regional development. As a result, we can expect that much future wastewater management effort at these sites will involve internal control rather than additional external measures.

(3) **Reduction of pollutant discharge not dealt with by classical technology** — The traditional control technology has dealt very successfully with readily oxidizable organic constituents and suspended solids arising in the manufacturing process. The colored and more slowly biodegradable effluent fractions persst through such control systems. Internal control can be expected to minimize discharge of both these effluent fractions. In addition, prevention of volatilization of selected effluent components during biological treatment, capable of contributing to atmospheric odor levels, can be viewed as a further objective of internal controls.

(4) **Reduction in wastewater management energy requirements** — A major objective of wastewater reuse historically has been energy conservation through heat economy. To this can now be added energy savings stemming from reduced hydraulic through put. Where reuse is accompanied by organic load reduction, further energy savings are possible through diminished bioaeration power requirements and increased burning of such organics in either traditional or innovative chemical recovery systems. The latter control measures may, however, require energy input as well, so that an optimization approach should also guide efforts in this direction. A parallel consideration involves the energy required to deliver water supplies to the mill itself, which can be reduced by water use economy.

Technological Aspects of Internal Control and Effluent Reuse

The current technological approach involves consideration of both volume and load reduction which are best discussed separately, recognizing that there are significant interrelations of the two.

A. Volume Reduction Considerations

To the present, the more significant volume reduction progress has materialized in the paper mill area, particularly among the non-integrated waste paperboard, tissue and fine paper mills. We have recently completed three studies (1) (2) (3) whose objective is to further the reuse of process wastewater in non-integrated paper mills. The program has proceeded in three phases as follows;

(1) the collection of information related to water reuse stressing operational limits to reuse related to changes in water quality,

(2) development of a computerized data retrieval system capability for entering new, and assessing existing information relating water quality and reuse potential,

(3) evaluation of the water renovation capability of new and proposed process equipment adapted to inclusion within the whitewater system.

The program has examined water reuse in the waste paperboard, fine papers and tissue/towelling segments of the industry with the following results:

(1) **Combination waste paperboard operations** — Studies at thirteen mills indicated that closure to 3000 gallons/ton could be readily achieved without encountering serious water quality-related problems. Beyond that point piping system revisions and material changes were indicated to reduce corrosion and abrasion problems. Plugging at such points as pump packing, gland seals, cylinder showers, bearing cooling jackets and machine felts was also encountered and attributed to fibre buildup in the recirculated water. The remedial approach has involved use of savealls, microstrainers, and fibre fractionators and concentrators. In-line slotted strainers are also graining use.

Two recent reports document the utility of a 'float-wash' fractionator for assisting in achieving boardmill water economy. According to Godin (4), water use and TSS losses at a boardmill were substantially reduced by installation of a float-wash fractionator to allow recycle of board machine whitewater to cylinder and felt showers. Holmrich (5) described such a proprietary device. Fractionation occurs by directing a stream against a screen and separating the long fibres from the fines with recycle of the separated streams for various applications.

(2) **Fine paper manufacture** — Twelve mills were examined in this study, all discharging less than 10,000 gallons/ton effluent. Plugging problems at wire and head box showers, bearing cooling lines and on the machine felts have been dealt with by removal of long fibre materials as in the board mills cited above. Felt hair removal is accomplished using horizontal rotating center-fed cylindrical screens of either nylon or stainless steel with a 120 to 140 mesh medium (6) (7).

In all but one of the mills visited fresh water was used for felt washing. This use remains as a large user of fresh water on the modern paper machine. While in the future it may be possible to reuse whitewater clarified by gravel filtration or other means for felt cleaning, tests carried out in mills forced to take this measure in times of extreme water economy indicate that premature deterioration of felts takes place (8). In the one mill visited which was using other than fresh water it was a 50 percent mixture of fresh water and dual media-filtered clarifier water and they reported no loss of felt life using this mixture. In the use of stronger needled felts which are better able to stand up to high pressure water jets, the tendency today is to use high-pressure, low-volume oscillating needled jet showers for intermittent felt cleaning. This significantly reduces water use.

(3) **Tissue and towelling manufacture** — Twelve tissue and towelling mills were studied to determine current reuse capability, problem areas and opportunties for further water use economy. Of these, eight used less than 10,000 gal/ton while two fell below 2000 gallon. The problems retarding further use were similar to those reported previously; namely (a) increased line, nozzle, wire, and felt plugging, (b) scale and corrosion, (c) product color, and (d) slime accumulation.

The corrective measures of a physico-mechanical nature have emphasized improvement in in-plant flotation saveall operation, use of in-line strainers, and cascading of water use on vacuum pump systems to permit further use of clarified whitewater. The mill currently achieving the highest degree of closure, Kimberly-Clark at Fullerton, California (9) accomplishes this through use of bentonite flocculation- or lime softening-assisted diatomacious earth filtration, with the latter approach preferred.

One effluent reuse approach that has not as yet been exploited to the same degree as direct internal recycle involves use of final biologically treated effluent as a partial source of untreated industrial water supply. Some success in this area, benefitting from the chemical coagulation and filtration often accompanying such water treatment, can be expected to further its application as reuse programs become even more intensive.

(4) **Cascading of bleach plant water use** — The bleach plant still represents the major point of water use in the pulp and paper industry. The most recent extensive examination of bleach plant water reuse patterns in North America was completed by Histed in 1972 (10). Considerable variation in total water use was observed ranging from 8000 to 23,000 gallons per ton. Extracts from Histed's report serve to illustrate the three main types of countercurrent washing being used in the most advanced mills. These may be described as (a) direct countercurrent, (b) split flow countercurrent, and (c) jump stage countercurrent. At present direct countercurrent and split flow countercurrent washing is restricted to bleacheries using the CEDED sequence. Jump stage countercurrent washing is used in bleacheries using either the CEDED or CEHDED sequences.

(a) **Direct Countercurrent** — Fresh water is applied on all of the showers of the final chlorine dioxide stage washer and on the first half of the showers of the chlorination stage washer. In addition, fresh water is applied for either wire wash or as a water doctor on all washers. Fresh water added to the seal pits for level control is kept to a minimum. The total bleachery effluent from bleacheries using this system ranged from 8100 to 10,300 USG/ADT. Differences in chlorination stage consistency caused most of the difference in volume from these bleacheries. There was very little difference in the amount discharged to the alkaline sewer from the first extraction stage. Bleacheries using this type of countercurrent washing have 317 s.s. washers on all stages.

(b) **Split Flow Countercurrent** — Fresh water is applied on all of the showers of the final chlorine dioxide stage and on half of the showers of the second extraction stage. The filtrate from the D_2 washer is split into 2 parts. Half is applied on the showers of E_2 washer and the other half is applied on the showers of D_1 washer. Similarly, E_2 filtrate is split between the showers of the D_1 and E_1 washers and D_1 filtrate is split between the showers of E_1 and C washers. Different mills use different positions for applying the split flows.

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condenser water and turpentine decanter underflow at an 850 ton per day linerboard mill were recycled to a cooling tower. Aeration of these process streams in this manner achieved a load reduction of 10,000 lbs. BOD per day due almost exclusively to air stripping of methanol and other volatiles. An inherent drawback lay, however, in the transfer of odorous volatiles such as terpenes and organic sulfides to the atmosphere.

This deficiency has been met by systems employing either air or steam-stripping with the stripped material being burned at a subsequent combustion unit. An example of such a system is that in operation at the Mead Corporation mill at Escanaba, Michigan. Initially this 800 ton bleached kraft mill installed a steam stripper handling hot water accumulator overflow, turpentine decanter overflow, evaporator condensates and miscellaneous hot odorous streams. The initial objective was to reduce odor release at the biotreatment system. This was accomplished using a fractional distillation column 53 feet high containing 24 trays, and steamed at a 2.5 percent rate, with noncondensibles and collected foul air burned in the lime kiln (13).

In 1973 a program was begun to determine whether the mill BOD load could be significantly reduced as well. Analysis showed that the stripper bottoms contained 15 to 18,000 lbs BOD daily and that 90 percent of this was accounted for by the methanol present in the condensates. Modifications to the system enabled the steam feed to be increased to 8 percent so that the residual BOD was reduced to 4 to 5000 lbs daily for a net reduction of 11 to 13,000 lbs daily. Total steam and power requirements are reported as 8000 lbs/hr of 60 psi steam and 65 HP for pumping condensates.

Kraft mill condensate stripping is now in use at seven United States mills. A recent report on this subject (14) reviews this technology and reports capital costs for systems ranging from air-stripping through partial to complete steam stripping at from 1000 to 5000 dollars per ton daily capacity, with comparable operating costs of 1.5 to 7 dollars per ton. Coupled with other control measures related to spill prevention, brownstock washing and excess paper machine effluent reprocessing, condensate stripping has the potential for achieving major progress toward closure of the pulp mill from an organic effluent discharge standpoint.

The experience at Southland's Houston mill also merits reference here as an example of condensate stripping being instituted to permit an existing activated sludge treatment system to successfully accommodate a major mill expansion through resultant BOD load reduction (15).

(b) **Sulfite condensate processing** — Currently underway at the Flambeau Paper Company, Park Falls, Wisconsin sulfite mill is a project directed toward demonstrating the possibilities for recovering methanol, furfural, and acetic acid as ethyl acetate from sulfite liquor evaporation condensates. The process being investigated involves steam stripping and activated carbon adsorption to achieve removal and separation of these components. This investigation expands on a project previously conducted at the Institute of Paper Chemistry (16). Another treatment approach pertinent to sulfite liquor condensates involves the upward adjustment of spent liquor pH prior to evaporation as to retain the volatile acids in the liquor concentrate, permitting their destruction in the liquor furnace rather than allowing their entry into the condensates. Previous studies have shown that upward adjustment of liquor pH from 2.5 to 4.0 could result in condensate BOD load reduction from 150 to 200 lbs per ton to 50 lbs per ton (17).

(3) **Bleach plant system closure** — Perhaps the most dramatic recent developments relate to efforts to close bleach plant systems and recycle resultant effluent to the pulp mill chemical recovery system. Two separate approaches being pursued include the Rapson process and the use of tonnage oxygen in place of the initial halogen-base bleaching stage.

(a) **Rapson process** — The Rapson process (18) is now receiving its full scale shakedown trial at Great Lakes' Thunder Bay, Ontario mill. It involves (1) substitution of some chlorine dioxide for chlorine in the initial stage, (2) extensive internal recycle to minimize total residual flow, (3) recycle of the residual bleach plant flow to the pulpmill brownstock washing system and ultimately through the recovery furnace to the causticizing process, (4) evaporation of white liquor for crystallization/separation of

The seal pits are interconnected in some bleacheries and not in others. The total bleachery effluent from mills using split flow countercurrent washing ranges from 9100 to 11,300 USG/ADT. Bleacheries using this type of countercurrent washing have 317 ELC washers on all stages.

(c) **Jump Stage Countercurrent** — This type of countercurrent washing is made necessary by the use of 304 stainless steel in the construction of the extraction stage washers and CEHDED bleacheries by the low temperature used in the hypochlorite stage. Fresh water is used on all showers of D_2 washer. Typically, D_2 filtrate is used on al showers of the D_1 washer and D_1 filtrate is used on all showers of the chlorination washer. Similarly, fresh water is used on the showers of E_2 washer and E_2 filtrate is used on the showers of E_1 washer. The total bleachery effluent from the mills using jump stage counterculrent washing ranges from 12,300 to 13,700 USG/ADT for the CEDED sequence and is much higher for mills using partial jump stage countercurrent washing in CEHDED bleacheries.

In subsequent studies Histed's group has shown that further volume reduction is possible to a residual flow of 1600 gallons per ton without adverse effects on bleached pulp properties. The objectives in this case was reduction to a level consistent with total bleach plant recycle through the pulp mill recovery cycle as in the Rapson process discussed below.

(5) **Pulpmill wastewater reuse** — A recent report by Timpe, Lange and Miller (11) catalogues the varied process waste streams available for reuse in a kraft pulp mill. These include digester relief, blow tank, and evaporator condensates, turpentine decanter underflow, and brownstock washing system decker filtrates. Specific points of reuse include the woodyard where log flumes, hot storage ponds, hydraulic and wet drum debarkers all provide reuse opportunities, particularly for condensates and excess paper machine water. Condensate use at such points as lime kiln scrubbing and brownstock washing is possible but limited in most cases by its odorous character. This can be mitigated by condensate stripping, discussed below. Decker filtrate reuse to achieve closure of the pulp washing system is believed possible with additional foam control measures and evaporator capacity. A major reduction in water use has been achieved by substitution of surface for barometric condensates on the multiple-effect evaporator system.

The St. Regis report suggests that kraft linerboard can be produced using only 5000 gallons per ton of fresh water, supplemented by 3500 gallons each from internal recycle and process waste sources. The report further lists reuse and recycle possibilities meriting additional study as follows, some of which had load reduction features as well.

(a) cooling water, including vacuum pump seal water, pump bearing water, and air conditioning cooling water to be recycled to cooling pond or tower.

(b) Use of activated carbon adsorption to control dissolved organics buildup in closed recycle systems. Use sidestream treatment to minimize equipment size.

(c) Removal of orgasics from turpentine underflow, possibly by steam stripping or activated carbon treatment.

(d) Reuse of blowdown stream from whitewater on pulp washer.

(e) Use of evaporator condensate, after organics removal, in pulp washing and as makeup water for paper machine showers.

(f) Possibly close the woodyard water cycle, which requires solids separation.

B. Load Reduction Consideratioss

Volume reduction measures in the paper industry generally carry no load reduction benefits except where (a) filtration or other particulate removal devices are used to enhance reuse possibilities at such points as felt washing, (b) condensates are stripped to remove volatile organic constituents, (c) system closure results in cycling of organic materials to a combustion point as in chemical recovery, incorporation of organic materials in the product, or is accompanied by special treatment processes such as activated carbon or resin adsorption. Some of these possiblities are reviewed below.

(1) **Combination waste paperboard system closure** — Closure of such systems from previous water use levels of 10 to 20,000 gallons per ton to 3000 gallons generally leaves BOD levels relatively unaffected. As water use is reduced below 1000 gallons per ton a rapidly increasing portion of the organic load is incorporated in the final product. At this point special care is required in (a) selection of production grades for which this practice is acceptable, and (b) specification of piping and equipment materials of construction resistant to accompanying corrosive conditions. Limited success has been achieved in total system closure, aided in some cases by use of external biotreatment as well to improve the quality of the recycled effluent.

(2) **Stripping of kraft and sulfite condensates** — Progress has been reported in North America in this area for both kraft and sulfite liquor digester and evaporator condensates as follows:

(a) **Kraft condensate processing** — An early approach to condensate stripping for BOD load reduction was reported by Estridge (12) in which evaporator condensates, barometric salt, and (5) optionally discarding the salt or its elective electrolytic reprocessing for bleaching chemicals manufacture. There is good reason to believe that the problems common to many new production technologies will be solved and that the full costs and environmental protection features of this process will soon be identified to guide its selective retrofitting into the existing pulping industry.

(b) **Oxygen bleaching** — Our recent studies of the oxygen bleaching process (19) provide evidence of the capability of this process to reduce sewered organic load should recycle and reuse of the first stage alkali-oxygen delignification effluent in the conventional kraft pulping chemical recovery process prove practical. Results obtained in the laboratory comparing softwood bleaching sequences indicated possible color, BOD and COD reductions of 85, 30 and 60 percent respectively when bleaching softwood pulp using an OCEDED sequence in comparison with the conventional CEHDED sequence.

(4) **Intermittent process loss control** — The operation of the chemical and physical processes for turning wood into paper represents a complex blending of batch and continuous processes. In the case of kraft pulping, current chemical recovery system designs call for collection of an average of 98 to 99 percent of the spent pulping liquor. The effluents from the unit processes involved vary with time, causing variations in mill effluents load, which may have an adverse effect on control process performance and final effluent characteristics as well. Aside from those load variations caused by changes in production schedules, a category of non-continuous variations has been identified stemming from tank overflows, process instability (e.g. evaporator carryover) spillage and leakage during process transfer, and cyclic operations (e.g. process cleanups or maintenance). Since sources and frequency of such load variation must vary substantially from one mill to another, there is a need for a management strategy for dealing with such losses.

We have undertaken the development of such a strategy for design of such loss recycle systems. It involves four distinct phases including (a) the characterization of raw waste variability for selected sources at a number of mills, (b) the selection and choice of suitable loss detection instrumentation, (c) assembly of computational programs and computer hardware for conduct of a field demonstration of the application of this management strategy, and (d) installation of the equipment and conduct of the field demonstration as a means of assessing its effectiveness.

Drawing on several preliminary studies of this subject (20) (21) the program has proceeded to its fourth phase at the Brown Company kraft mill. The actual potential for loss collection and recycle varies from one mill to another, primarily as a result of differences in marginal liquor evaporation capacity. It is felt, however, that the ability to capitalize on that potential can be materially enhanced by application of the evolving management strategy.

(5) **Activated carbon adsorption** — Capability of activated carbon for upgrading the compositional quality of non-integrated paper mill effluents has been demonstrated in two major pilot plant studies discussed previously (22) (23). These findings have, however, not as yet been extended to a point that would support recycle of carbon treated effluent as makeup supply to a mill water treatment system to minimize its water requirements. Such further studies await an assessment of large scale experience at the Fitchburg, Massachusetts joint treatment facility.

(6) **Resin separation for recycling pulping effluent organic constituents** — While this subject continues to command research attention using both granular and membrane-type resins, practical applications have been slow in materializing in the United States. The single reported application continues to be the Green Bay Packaging unit where a high solids concentration semi-chemical board machine whitewater system is balanced by processing 20 gpm of excess whitewater. The separated organics are returned to the chemical recovery system while the clear water from this reverse osmosis unit is used as fresh water for pump seals (24).

Economic Aspects of Internal Control and Effluent Recycle

Two recent studies in this area merit attention in this report. The first explored the response of external treatment capital and operating costs to incremental changes in pulp mill effluent load from production processes, while the second examined the effluent volume sensitivity of costs for advanced effluent treatment directed toward process closure and effluent reuse.

A. Response of External Treatment Capital and Operating Costs to Incremental Changes in Pulp Mill Effluent Loads

This subject was addressed by the National Council in 1973 (25). It stemmed from a recognition that widespread application of costly biotreatment had created an additional impetus toward (a) improved retention of organic materials in pulping process systems and (b) further effluent volume reduction. It sought to further encourage such measures by identifying their incremental economic value in controlling external treatment costs.

While the findings were viewed as illustrative only, they identified the relative contributions of flow, BOD and suspended solids to biotreatment system capital and operating costs, so that individual attention could be focussed on incremental sources of these effluent load elements. Analyses of this type have been instrumental inadvancing the application of the optimization approach toward successful combination of internal and external load reduction measures.

B. Effluent Volume Sensitivity of Costs for Advanced Effluent Treatment

In 1974 the National Council published contractor-prepared engineering cost estimates of overall industry costs for achieving "zero discharge of pollutants." These estimates were premised on the assumption for estimating purposes that desalination program technology, such as multistage flash evaporation, could achieve this objective. The contractor found (26) that overall industry capital costs (beyond high-efficiency biotreatment) could reach $4.3 billion (in 1972 dollars) and that if industry water usage were reduced by 50 percent, the estimated capital costs could be reduced to $2.5 billion. An attempt was then made to estimate the costs for achieving such a degree of water use economy. A preliminary estimate indicated these costs could reach $900 million. Some of the technological steps that were considered are summarized below for specific mill types.

(1) **Bleached kraft production**

(a) conversion from wet to dry debarking

(b) use of pressurized de-knotting and screening

(c) recycle of chlorination bleach stage effluent

(d) conversion of barometric to surface condensates

(e) collection, treatment and reuse of press and vacuum pump water

(2) **Groundwood and semichemical production**

(a) conversion from wet to dry debarking

(b) use of pressurized screening

(c) collection, treatment and reuse of press and vacuum pump water

Based on experience with previous engineering estimates of this type, it is likely that practical application of these measures would entail considerably more capital cost than indicated.

Summary—Developmental Trends and Possible Areas for Cooperative Study

The high cost of biotreatment and its auxiliaries for achieving mandated residual effluent levels represents the major impetus toward reductions in mill process volumetric and organic load. Reductions are being pursued independently in each area, within a framework of overall reduction objectives, since it is recognized that reduction in one area does not automatically produce benefits in the second.

The principal process areas with volume reduction potential remain the paper machine and bleach plant, followed by the woodyard and liquor evaporation systems. Those with organic load reduction potential are pulping liquor separation and reprocessing, intermittent loss control (spillage), bleach plant effluent recycle to pulpmill chemical recovery (combustion) and near complete paper machine closure.

The major role of new manufacturing processes in achieving further load reduction is evidenced by current attention to condensate stripping, new pulp washing and screening procedures, and efforts to close the bleach plant through changes in halogen use, separation of chlorides from pulping liquor intermediaries and substitution of oxygen bleaching.

Opening of new routes to further progress in papermaking volume reduction awaits more study of water quality requirements at specific reuse points and selection of means to produce water of such quality from individual whitewater streams or total mill effluent (particularly in non-integrated mills).

There are significant opportunities for cooperative investigation under the US-USSR bilateral environmental cooperation program that await further implementation in the pulp and paper industry. Among these can be included a number that bear on effluent recycle and load reduction technology development as follows:

(1) Determination of water quality needs for both pulp and paper manufacture as a guide to development of specific effluent treatment objectives, particularly for in-process effluent streams which are candidates for further reuse.

(2) Examination of the economic and treatment optimization aspects of varying degrees of condensate stripping, stressing the most economic level of use and source of stripping steam and the incremental savings achieved in use of existing biotreatment systems, or their possible future avoidance or minimization for a new generation of more highly closed pulp mills.

(3) Development and implementation of a management strategy for detecting, collecting and reprocessing intermittent process material losses, particularly from pulping, screening and liquor evaporation stages. ☐

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Closed Up Water Supply Systems and Reuse of Treated Effluents in the Pulp and Paper Industry of the USSR

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Development of effluent-free water management system in the pulp and paper industry is constantly becoming a more and more acute task solved within the scope of the industry pollution control program.

An expanded environment control program is adopted and put into effect in the pulp and paper industry of the USSR. Reduction of fresh water consumption as well as decreasing the volume of water required for the main production processes envolving the traditional technology constitute important elements of this program.

Pulp and paper processing requires considerable amounts of water of various quality since most of the technological processes take place in equeous mediae in which the basic chemical reactions proceed.

Heat exchanging, transportation of fiber and chemicals, sheet forming procedures on paper and board machines, removal of different impurities and sludge in the process of production and effluent treatment, etc. are accomplished with the help of water.

Mills manufacturing one or a number of product grades use complicated combinations of water supply and water discharge systems. Characteristic features of such systems is the application of different water types intended for intradepartmental and inplant recycling as well as for repeated and successive usage.

The total fresh water demand of the domestic pulp and paper mills amounts to 9.5 M cu m/t with the whitewater consumption comprising 7.8 M cu m/t (1).

Evaluation of the water management at the domestic mills shows (2) that water is supplied mainly from the flowing surface water sources. Consumption of groundwater comprises nearly 1.0%; fresh water requirement for the mill economy needs does not exceed 2.0% of its total consumption value. The amount of water recycling outside the given department, i.e. the quantity of white water returned to the same department after it undergoes a special treatment procedure is insignificant and does not exceed as a rule 10%.

Interdepartmental water reuse—when effluents of one department replace fresh water in the other—make up a greater volume something around 25%. Reuse and recycling of water inside a department is on the average within 65-70%.

Steam electric stations at the mills are provided in general with uniflow water supply systems and the consumption of fresh water for these purposes is sometimes as high as 50% of the total water requirement. This water may then be applied for processing purposes and according to the classification adopted in the pulp and paper industry it refers to successively used water. It should be also pointed out that the specific water demand as envisaged by the above classification is evaluated in the pulp and paper industry of the USSR from the total volume of water consumpted by the mill. That is why the specific water requirement increases at the expense of auxiliary shops of the mill and therefore it cannot be compared with corresponding figures reflecting the performance of mills in other countries.

With the production of alcohol, yeast, furfurol, veneer, vanilin, fiber boards, etc.—items not associated directly with the manufacturing of pulp and paper products—water consumption makes up on the average nearly 9%.

Some 18% of the total volume of water consumed are accounted for other needs of the mill economy—water preparation, boiler rooms, repair shops, compressors, oxygen supply stations, effluent treatment facilities, etc.

Irreversible water losses at the removal of recovered stock, at the evaporating and burning of liquor, lime sludge roasting, etc amount to approximately 6.0%.

In this manner the consumption of fresh water for the production of main items in the mill varies within 24 to 63% of the total requirement.

With the development of water closed up systems for pulp and paper mills it is necessary at present to take into account not only the principle production processes which are responsible for the major part of pollutants in the waste water of he modern industrial complexes. The above objects are also to be considered. All the problems associated with the water economy of a mill when solved integrilly will permit the develop of an actual closed up system as well as to start solving the final task—the construcion of a waste-free mill.

Users of the processing water with regard to regards requirements to its quality may be divided into two groups. Users of the first group refer to evaporator and turbine surface condensers, compressors, oxygen supply stations and the like where only physical contamination/temperature rise/of the water takes place without affecting its chemical composition. Such a water may be repeatedly used after correction of the temperature to the required value.

The second group of users may be represented by the pulp and paper principle production processes where along the physical changes alterations in its chemical composition occur: in this case appear suspended solids and colloidal particles. In view of the great diversity of such users they may be in their turn divided into two sub groups.

Water of the first subgroup is contaminated mainly with suspended solids: fibers, fillers, etc. It may be used without retreatment or clarified in one or a few stages with the purpose either to return it to the production line or discharge it into a receiving stream. At the pulp and paper mills in the USSR water is treated with the application of the following equipment: scraper and conical type save-alls ("Antuan"); vertical settling tanks; suspended solids clarifiers; "Sven Pedersen", "Adka", FL-3 and FL-4 flotation type save-alls; "Vako" and "Kinzle" revolving gauze filters and disk filters.

Such units or white water clarifying systems are applied for water treatment prior to reuse it in the wood room, groundwood mill, on paper and paperboard machines.

So for reducing the consumption of fresh water by 2 or 3 times clarified and bark containing effluents of the wood room are returned to the barking drums. Along with the application of effluents from some other departments this will permit cutting the consumption of fresh water in the wood room down to 8 cu m/t of pulp.

Production lines of the second subgroup associated mainly with pulp manufacturing processes contaminate water with dissolved organic and mineral substances. These effluents may also contain fibers. They can be reused without preliminary treatment—for instance filtrates of one bleaching stage may be directed to another at combined countercurrent washing flow sheets; some condensates from the evaporation can be used for washing of brown stock. But nevertheless the greatest part of the waste water for this production subgroup should undergo complicated multistage treatment procedures at the external effluent treatment systems inclusive prior to be reused.

The efficiency of a mill water supply system is evaluated by two figures: the specific requirement of fresh water per ton of manufactured product and the water turnover coefficient which is determined by the relation of summed up consumption of white water, repeatedly and successively used water to its totally consumed value.

Data illustrating specific consumption of fresh water at the USSR mills in comparison with the 1974 standards as with regard water requirement and water discharge are given in Table 1.

As seen from the below figures the pulp and paper mills in the USSR have considerable potentials for the further improvement of water management systems.

It should be contributed to the standards effective in the USSR according to which the degree of recycling and repeatedly used water should not be under the given below values expressed in percents:

unbleached kraft pulp	73
bleached kraft	82
printing and writing papers (from purchased pulp)	62
container board (from purchased pulp)	78

A number of mills in the USSR use treated effluents for the production of boxboard from waste paper (4). So some mills apply a system developed by the Pulp and Paper Research Institute in the Ukraine with the provision for separating on fractionators good fiber followed by treating of water with proper reagents in settling tanks prior returning it to the production line. Due to the above system the consumption of fresh water is considerably lowered making up to 7-15 cu m/t of manufactured products.

Description	Specific consumption of fresh water, cu m/t Consumption range according to mill 1974 standards	 With regard to records /1975/
1	2	3
Kraft pulp:		
unbleached	65-354	140
bleached	220-766	220
Sulphite pulp:		
unbleached	126-520	145
bleached	275-705	315
rayon	360-809	500
Paper:		
newsprint	50-90	55
writing and printing	74-164	85
raw corrugating	41-145	70
wrapping	41-207	45
Container board	31-140	70

Table 1

In view of the considerable number of external effluent treatment facilities available in the pulp and paper industry of the USSR decisions were made to use clarified white water in the production process.

Some mills follow the path of increasing the coefficient of used white water bringing the fresh water consumption down to 1.5 - 3.0 cu m/t.

At the same time the production experiences herewith considerable difficulties associated with foaming, equipment corrosion, intensification of biological overgrowth, increased number of paper and paperboard sheet breaks on the machines, etc.

On the ground of studies carried out in the All-Union Pulp and Paper Research Institute /Leningrad/ it was shown that most of the above difficulties can be avoided by using waste water treated biologically or in combination with chemical means.

The potentiality of using biologically treated effluents instead of fresh water in the paperboard production had been investigated.

It was established that the properties of the biologically treated paperboard production effluents as well as treated pulp and board production mixed waste waters meet the requirements to the quality of processing water for manufacturing unbleached as shown below:

1. Solids matter content, mg/l .... ≦50
2. Dissolved substances content, mg/l ...... ≦4700
3. BOD_5, mg0_2/l .... ≦400
4. COD, mg0_2/l .... ≦1200

On the ground of laboratory and pilot plant studies an effluent-free paperboard mill reconstruction project has been developed. Fresh water consumption of this effluent-free mill started in June 1975 amounts to about 3.5 cu m/t of board.

The obtained results permit to record the following items:

- solids matter content in the tray water did not change considerably;

- increased consistency of dissolved substances from 860 up to 2400 mg/l as well as COD from 1200 up to 1830 mg0_2/l in the tray water resulted in increasing the corresponding properties in the water supplied to the treatment facilities from 584 up to 1835 mg/l and from 950 up to 1700 mg0_2/l respectively;

- effluent contamination limiting values achieved on the 8th or 10th day of the experiment were not exceeded;

- some temperature rise—from 3 to 7°C—of waste water and treated effluents supplied to the mill;

- biological treating facilities functioned under stable processing conditions.

It should be pointed out that the processing equipment was not affected by corrosion or biological growth.

Promoting of the mill water closed up system elements is associated with considerable capital investments and operating costs caused by replacing some old equipment by new one including in the flow sheet new facilities, by laying additional pipelines, by foam and scale control, corrosion, increased biological growth, odor control, etc. It may be also due to operational problems and in a number of cases to the necessity to collect and return accidental mill emissions.

Considerable costs associated with the development of such water management systems are to be offset not only by the general ecological effects. They should also bring to a certain economy in the consumption of raw materials, chemicals and heat energy as well as result in the improvement of property qualities of manufactured articles and in the performance of the functioning effluent control facilities. It must also help to decrease the expenditures for the construction of new pollution control installations.

Proceeding from the above initial designing data were worked out in the VNPO bounprom for the reconstruction of a functioning mill. It had been done with the object to develop a highly efficient water closed up system for a 280,000 t/y bleached kraft pulp and container board mill (a pilot plant). It should be noted that this mill is provided with external facilities for biological and chemical treatment of waste waters.

At developing a water closed up system for the principle technological processes the supply of hot and warm water should be proceeded through a water-cooling tower for its reuse in the heat exchanging units. Intensively clarified surplus water from the board mill and the water from the effluent treatment facilities is to be also applied. It refers as well to the development of a system for recycling clarified water with the application of the water from the power stations ash removing installations and the effluents from the external treatment facilities. Therewith the problem had been to avoid mixing up waters of different composition.

Owing to the necessity to remove excessive mineral salts from the mill system, provisions were made for demineralizing partly the effluents treated at the external facilities with the object to replace fresh water.

Provisions were made to have a separate sewer system and evaporate the mostly contaminated effluents of the recovery plant as well as of the cooking/washing department. Evaporation is to be carried out integrally with the highly concentrated effluents of the demineralization unit.

Provisions are also made for cooling water after water-cooling towers since its temperature may be relatively high especially in summer time.

One way of developing such a system is to use to the utmost white water in the production process and to exclude water completely from the power departments of the mill as well as to treat separately industrial and municipal effluents.

The system is to incorporate additional installations for treating local effluents. So suspended solids filters are to be applied as a second stage for clarifying paperboard machines tray water, centrifuges should be used for additional separation of the green liquor sludge, hydrocyclones are to be applied for treating ash removing water from the power stations, etc.

Reconstruction of the washing department is an important condition for the development of a pulp mill water closed up system. The two installations available at the integrated mill comprised of three double zone pressure filters ensure according to the project 97% bleeding of the waste liquor. But under new conditions this is to be considered as insufficient.

According to the obtained test results the optimal efficiency may be achieved at installing a high intensity press unit to be used as an additional stage. Herewith the top consistency of the pulp after the press is to be within 50% with the working consistency in the range of 38 to 40%. In this case the designed liquor bleeding efficiency at washing is to amount 99% while the real value is about 98.5%.

It should be pointed out that the utilization of the sludge from the effluent treatment facilities is incorporated in the flow sheet for paperboard production. Sludge treatment processes and recommendations for its use were also developed and checked under pilot plant conditions in the All-Union Pulp and Paper Research Institute in Leningrad. In this way it is supposed to make the kraft pulp and container board production not only effluent-free but to a greater extent also waste-free.

What is more, design projects for the utilization of treated effluents in the production of bleached kraft pulp and rayon pulp grades are checked at present. These projects after their approval will permit to have in the USSR mills featured for possessing highly efficient water closed up systems. □

Protocol

Protocol of the fifth Meeting of the USA and USSR delegations on the problem of Prevention of Wastewater Pollution from Industrial and Municipal Sources (Moscow, USSR, September 11-25, 1977).

In accordance with the Memorandum of the Fifth Meeting of Joint USA-USSR Commission on Cooperation in the field of Environmental Protection (Moscow, November 1976) the USSR and USA delegations Meeting on the problem of Wastewater Treatment was held in Moscow, September 11-25, 1977.

The American delegation was led by Mr. Harold P. Cahill, Jr., Director of Municipal Construction Division, US Environmental Protection Agency.

The Soviet delegation was headed by Prof. S.V. Yakovlev, Director of the Scientific-Research Institute VODGEO, Gosstroi USSR.

The list of participants is attached in Appendix I.

In the course of the visit the following was accomplished:

1. A Symposium on the topic of Recirculating Water Supply Systems and Reuse of Treated Effluents at Industrial Enterprises was held in Moscow.

2. The results of fulfilment of the 1977 Program of Cooperation were discussed.

3. Coordination of the Working Program for 1978 was achieved.

1.

In the course of the Symposium 14 papers were delivered: 7 papers from each side (Appendix II).

All papers were received with great interest and were followed by a lively discussion.

The delegations have agreed that each side will publish all papers in the required number of copies in its own language prior to February 1, 1978 and will distribute them among interested organizations. The sides will exchange 10 copies each of the published Proceedings of the Symposium.

2.

In the course of the visit the specialists have discussed the results of scientific work being carried on according to the Program of Cooperation, have exchanged opinions on future trends in the area of wastewater treatment, became acquainted with bench-scale units used for conduct of scientific research and have exchanged scientific and technical literature.

3.

The delegations discussed and agreed on the 1978 Program of Cooperation (Appendix III).

Both sides have agreed that in the course of the delegations Meeting in 1978 the implementation of the Cooperation Program will be discussed and Symposia on the following topics will be held:
— "Advanced equipment and facilities for wastewater treatment" (USA, March 19-April 2, 1978)
— "Facilities for tertiary treatment of biologically treated effluent with removal of biogenous elements" (USSR, August 20-September 2 1978)

In preparation for the Symposium to be held in the USA the following was agreed upon:

- each side will present 5-7 papers in a Symposium;
- both sides will exchange the titles of reports to be delivered prior to January 15, 1978;
- both sides will exchange the texts of the reports both in Russian and in English prior to February 15, 1978.

Both delegations have agreed that 2 Soviet specialists will visit the USA for 2 months each in May-June 1978, and 2 American specialists wil visit the Soviet Union for 2 months each in May-June, 1978.

These specialists will have the opportunity to study scientific research and design work of various organizations as well as treatment facilities for municipal and industrial wastewater treatment in both countries. The detailed exchange programs will be agreed upon in March 1978 in the course of the delegations Meeting in the USA. Exchange specialists will be carried out on the basis of equal and "receiving-side-pays" basis.

Both sides came to the conclusion that it would be beneficial during the next five years to exchange specialists and technical documentation for the construction of pilot facilities for wastewater and sludge treatment. These facilities will be utilized for the conduct of joint research projects.

Exchange of technical documentation and research work will be conducted on the basis of equal and "receiving-side-pays" basis.

Certain proposals of both sides on the exchange of technical documentation for pilot plants construction will be considered in the course of the delegations Meeting in August 1978.

The delegations have noted that in accordance with the information given by the American Side:

—The Soviet specialists in pulp and paper industry will visit the U.S. in late January or early February 1978 and the U.S. side will visit the Soviet Union during the Summer of 1978.

—There will be mutual exchanges in 1978 in the areas of the chemical and petroleum industries at dates to be decided upon.

—The details of these industries exchange would be presented for confirmation at the Joint Committee Conference in Washington, D.C. in November 1977.

In the course of the Meeting delegations visited industrial and municipal treatment facilities in Moscow, Kiev, Chernigov and discussed the present time state of the problem of wastewater treatment with the specialists of VNII VODGEO, UkrNIIB, Ukrvodokanalproekt, The Kharl Department of VNII VODGEO and various organizations in Tbilisi.

Information on creation of recycling sewerage system of an petro-chemical enterprise being constructed and the exchange of opinions on the problem of methods of electro-coagulation for wastewater treatment were of special interest for the American delegation.

The Sides have expressed their satisfaction that the Meeting was conducted on a highly scientific and technical level in an atmosphere of friendship and mutual understanding thus contributing to the further development and strengthening of cooperation in the field of environmental protection.

This Protocol was signed on September 23, 1977, in two copies in Russian and English, both texts being equally authentic.

From the U.S. Side

Mr. Harold P. Cahill, Jr.
Chairman of the US delegation

From the Soviet Side

Prof. S. V. Yakovlev
Head of the Soviet delegation

Appendix 1

List of participants at the Symposium "Recirculating Water Supply Systems and Reuse of Treated Effluents at Industrial Enterprises"

From the American Side

Harold P. Cahill, Jr.
Chairman of Delegation
Director, Municipal Construction Division, U.S. EPA

William J. Lacy
Deputy Chairman of Delegation
Principal Engineering-Science Advisor, Office of Research and Development, U.S. EPA

Andrew Paretti
Consultant, Office of Water Program Operations, U.S. EPA

Dr. Isaiah Gellman
Executive Vice President, National Council of the Paper Industry, for Air and Stream Improvement

Donald Tillman
Chief Engineer, City of Los Angeles, California

Franklin Sebastian
President Wastewater Equipment Manufact. Assoc.

Robert Denbo
Chairman, American Petroleum Institute on Environmental Control

Rear-Admiral
Eugene Peltier (U.S.N. Ret.)
Chairman Management Advisory Group U.S. EPA

Raymond Rimkus
Chief, Maintenance Operations
Metropolitan Sanitary District of Greater Chicago

Prof. Alex Malyshev
Colorado College
Interpreter, U.S. Dept. of State

From the Soviet Side

Prof. Yakovlev S.V.
Head of Delegation
Director, VNII VODGEO

Shvetsov V.N.
Vice-director, VNII VODGEO

Myasnikov I.N.
Head of Laboratory, VNII VODGEO

Dr. Alferova L.A.
Head of Laboratory, VNII VODGEO

Dr. Skirdov I.V.
Head of Laboratory, VNII VODGEO

Ponomarev V.G.
Head of Laboratory, VNII VODGEO

Voronina M.A.
Senior Engineer, VNII VODGEO

Moskvitina E.D.
Senior Researcher, VNII VODGEO

Lobacheva E.A.
Senior Interpreter, VNII VODGEO

Appendix 2

List of papers presented at the Symposium "Recirculating Water Supply Systems and Reuse of Treated Effluents at Industrial Enterprises"

From the U.S. Side

W. J. Lacy
The Closed-Loop Cycle for Industrial Wastewater The Future Pollution Solution.

I. Gellman
The Role of Wastewater Reuse and Process Loss Control in Paper Industry Wastewater Management.

D.C. Tillman
Water Reclamation as a New Dimension in Growth for Los Angeles.

F.P. Sebastian
Municipal and Industrial Wastewater Treatment and Reuse.

R.T. Denbo
Reduction and Reuse of Process Wastewater in a Petroleum Refinery.

E.J. Peltier
Recycling—the Key to One Steel Mill's Pollution Control Program.

R.R. Rimkus
Reuse of Process Water from a Large Steel Plant.

From the Soviet Side

Alferova L.A., Nechaev A.P., Markov P.P.
Fundamentals of Creating Closed-Loop Water Supply Systems at Industrial Enterprises.

Sukach S.P., Kirichenko A.G., Shenderovich, I.B., Antonchuk J.I.
Conditions of Municipal Effluents Use for Making-Up of Recycling Water Supply Systems.

Lukinih N.A.
The Peculiarities of Municipal Sewage Effluent Utilization in Industrial Plants.

Gasanov M.V., Amirova S.M.
To the Question of Municipal Treated Sewage Use in Industrial Water Supply of the Apsheron Peninsula.

Ioakimis, E.G., Saifutdinov R.Z., Yefimova A.K.
Usage of Purified Waste Water in Refinery Circulating Water Systems.

Sukach S.P., Klovatskiy Yu.D., Shenderovich I.B.
Utilization of Sea Water in a System of Recycling Water Supply of Industrial Enterprises.

Nikitin Y.V.
Closed up Water Supply Systems and Reuse of Treated Effluents in the Pulp and Paper Industry of the USSR.

Appendix 3

USA-USSR Cooperation of Working Group on Prevention of Water Pollution from Industrial and Municipal Sources For 1978.

Title	Form of Work	Responsible for			Expected Results
		From the USSR	From the USA	Time	
1. Modernization of existing and development of new combined facilities with high efficiency for wastewater treatment, including hydrocyclones, multistage settlers, flotators, facilities with utilization of technical oxygen, investigation of usage of flocculants and coagulants.	Joint development of themes, scientific information and specialists delegation exchange. Symposium on: "Advanced equipment and facilities for wastewater treatment" (USA, Cincinnati, March 19-April 2, 1978, 8 specialists). Symposium on: "Facilities for tertiary treatment of biologically treated effluents with removal of nutrients" (USSR, Moscow, August 20-September 2, 1978, 8 specialists).	VNII VODGEO Gosstroi USSR	EPA	1978	Improvement of the efficiency of existing and development of new treatment facilities, reduction of reagents and cost of wastewater treatment.
Development of tubular and plate settlers			EPA	1980	Recommendations for use of settlers for wastewater treatment.
Development of hydrocyclones and pressure flotation units		VNII VODGEO Gosstroi USSR		1980	Recommendations for designing hydrocyclones and pressure flotation units.
Development of open aeration tanks of "Marox" type with the usage of technical oxygen			EPA	1980	Development of open aeration tanks with the usage of technical oxygen.
Development of closed combined aeration tanks of "Oxitank" type with the usage of technical oxygen		VNII VODGEO Gosstroi USSR		1980	Development of closed aeration tanks with the usage of technical oxygen.
Development of multi-media filters with gradually descending particle size distribution		VNII VODGEO Gosstroi USSR		1979	Recommendations for designing filters for treatment and final treatment of wastewaters.
Development of multi-media filters and facilities with continuing washing			EPA	1979	Recommendations for construction of multi-media filters.
2. Intensification of wastewater treatment processes in petro-chemical, chemical, petroleum refining and pulp and paper industries.	Information and delegation exchange	VNII VODGEO Gossroi USSR	EPA	1979	Increasing of wastewater treatment efficiency of existing treatment plants, introduction of new treatment schemes, maximum usage of treated effluents in recirculating systems.
Intensification of wastewater treatment processes in petroleum refining industry.		VNII VODGEO Gosstroi USSR		1979	Development of treatment scheme of a petroleum refining plant using mechanical, physical-chemical and biochemical methods.

Title	Form of Work	Responsible for			Expected Results
		From the USSR	From the USA	Time	
Intensification of wastewater treatment processes in petro-chemical and pulp and paper industries.			EPA	1979	Development of treatment scheme of pulp and paper and petro-chemical enterprises using reagents.
3. Development of highly efficient methods and facilities for municipal sewage treatment with removal of biogenous elements; usage of treated effluents in recycling systems at industrial enterprises.	Joint development of themes, information and delegation exchange.	VNII VODGEO Gosstroi USSR	EPA	1980	Development of new treatment facilities for prevention of water basins eutrofication; development of new treatment systems with maximum usage of treated effluents in recycling systems at industrial enterprises.
Development of methods and facilities for nitrates and nitrites removal.		VNII VODGEO Gosstroi USSR			Development of recommendations for facilities designing.
Development of optimum schemes of treatment facilities for removal of biogenous elements.			EPA		Development of recommendations for facilities designing.
4. Treatment of wastewater sludges.	Information and delegation exchange.	VNII VODGEO Gosstroi USSR		1980	of wastewater sludge Reduction of cost treatment, increasing of treatment facilities efficiency.
Stabilizing and dewatering of wastewater sludges.		VNII VODGEO Gosstroi USSR	EPA		Recommendations for designing of facilities for stabilization and dewatering of wastewater sludges.
Technology and facilities for heat treatment and utilization of wastewater sludges.			EPA		Recomendations for designing of facilities for heat treatment and utilization of wastewater sludges.
5. Visit of 2 American specialists to the USSR for 2 months each on problems of wastewater treatment.	Acquaintance with research work of Soviet organizations and research institutes and participation in scientific researches.	VNII VODGEO Gosstroi USSR	EPA	May-June 1978	Studying of the USSR experience in the field of wastewater treatment.
Visit of 2 Soviet specialists to the USA for 2 months each an problems of wastewater treatment.	Acquaintance with research work of American firms and organizations and participiton in scientific researches.	VNII VODGEO Gosstroi USSR	EPA	May-June 1978	Studying of the US experience in the field of wastewater treatment.

Appendix 4

USSR - USA
The Program of the Symposium
Moscow, VNII VODGEO, GOSSTROY, USSR
September 12-13, 1977

Monday, September 12

8:45 a.m.	Registration
9:15 a.m.	Opening ceremonies of the Symposium VNII VODGEO—Yakovlev S.V., Director of Sojusvodocanalproject—Y.N. Andrianov. EPA—Cahill, H. "Fundamentals of Creating Closed-loop Water Supply Systems at Industrial Enterprises"—L.A. Alferova, Nechaev A. (VNII VODGEO)
10:25 a.m.	"The Closed-Loop Cycle for Industrial Wastewaters—The Future Pollution Solution" —W. Lacy (EPA)
11.05 a.m.	Discussion.
11:20 a.m.	Break.
11:35 a.m.	"The Use of Treated Effluents in Recirculating Water Supply Systems"—E.H. Yoakimis, K.Z. Saifutdinov, A.K. Efimova (BashNIIMP).
12:15 p.m.	"Recycling and Treatment of Wastewater at Industrial Plants"—E. Peltier (USEPA).
12:55 p.m.	Discussion.
13:10 p.m.	Break.
14:10 p.m.	"The Recycling of Sea Water in Industrial Water Supply Systems"—S.P. Sukac, Y.D. Klovatsky, I.B., Shenerovich (VNII VODGEO).
14:50 p.m.	"Industrial and Municipal Water Reuse"—F. Sebastian (EPA).
15:30 p.m.	Discussion.
15:45 p.m.	Break.
16:00 p.m.	"The Application of Treated Effluents to Industrial Water Supply of the Apsheron Peninsula"—M.V. Gasanov, S.M. Amirova (VNII VODGEO).
16:40 p.m.	"Water Reclamation—A New Dimension Growth for Los Angeles"—D. Tillman (EPA).
17:20 p.m.	Discussion.

Tuesday, September 13

9:00 a.m.	"Peculiarities of Using Treated Municipal Wastewater at Industrial Plants"—N.A. Lukinych (NII KViOV).
9:40 a.m.	"Reuse of Process of Water from a Large Steel Plant"—R. Rimkus (EPA).
10:20 a.m.	Discussion.
10:35 a.m.	Break.
10:50 a.m.	"The Use of Treated Municipal Effluent as Make-up Water for Recirculating Water Supply"—Y.B. Shenderovich, S.P. Sukach, Kirichenko A.G. (VNII VODGEO).
11:30 a.m.	"The Role of Wastewater Reuse and Process Loss Control In Paper Industry Management —I. Gellman (EPA).
12:10 p.m.	Discussion.
12:25 p.m.	Break.
13:25 p.m.	"Recirculating Water Supply and Reuse of Wastewater in Pulp and Paper Industry"—Y.V. Nikitin (VNPO Bumprom).
14:45 p.m.	Discussion.
15:00 p.m.	Break.
15:15 p.m.	Adjournment. VNII VODGEO—S.V. Yakovlev, EPA—H. Cahill.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1978 0—253-996